SOLAR ECLIPSE 2024: WHAT YOU NEED TO KNOW p. 24

MARCH 2022

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CONTENTS

40

MARCH 2022
VOL. 50, NO. 3

ON THE COVER

Jupiter's swirling clouds are just one example of a solar system filled with amazing weather. NASA/JPL

FEATURES

16 COVER STORY
Wild weather of the solar system
Today's forecast: Scalding temperatures, extreme winds, and a chance of diamond downpours. **RANDALL HYMAN**

24
First look at the 2024 total solar eclipse
On April 8, 2024, millions of Americans will watch the Moon entirely blot out the Sun.
MICHAEL E. BAKICH

32
Sky This Month
Plenty of planets at dawn.
MARTIN RATCLIFFE AND ALISTER LING

34
Star Dome and Paths of the Planets
RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY

40
When the Atomic Age met the Space Age
Is space for exploration or militarization? Early rocket pioneers like Wernher von Braun thought it might be prudent to pursue both.
FRED NADIS

46
Planetary nebulae in color
These dying stars are going out in style, showing off rich greens, blues, and reds you can enjoy through your eyepiece.
ALAN GOLDSTEIN

50
Beyond the Messier marathon
If you're tired of running the same old race, here's a new route through the night sky.
MICHAEL E. BAKICH

54
Leap into the Large Magellanic Cloud
The Milky Way's close companion is more than just a single deep-sky object — it's a bustling galactic metropolis waiting to be explored.
MICHAEL E. BAKICH

58
Add the Polarie U to your toolbox
Vixen's star tracker will suit your observing needs, no matter your experience level.
RAYMOND SHUBINSKI

62
Ask Astro
Cosmic fireworks.

COLUMNS

Strange Universe 13
BOB BERMAN

Observing Basics 14
GLENN CHAPLE

Secret Sky 15
STEPHEN JAMES O'MEARA

Binocular Universe 60
PHIL HARRINGTON

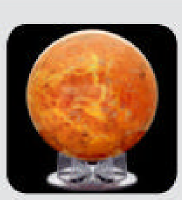
7
QUANTUM GRAVITY
Everything you need to know about the universe this month: the hollowed-out core of a nebula, dazzling aurorae, a how-to for announcing alien life, and much more!

IN EVERY ISSUE

From the Editor 5
Astro Letters 6
Advertiser Index 61
Reader Gallery 64
Breakthrough 66

ONLINE FAVORITES

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.



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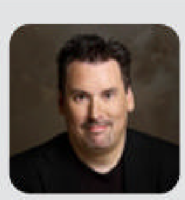

Dave's Universe
The inside scoop from the editor.

News
The latest updates from the science and the hobby.

Ask Astro Archives
Answers to all your cosmic questions.

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The eclipse of a lifetime

A spectacular pairing of the Sun and Moon will create a magical solar eclipse in 2024. It will become the most observed eclipse in history. IMAGE: DON SABERS AND RON ROYER; PROCESSING: MILOSLAV DRUCKMÜLLER

As I write this, I'm preparing for an adventure. I'll soon be headed to Santiago, Chile, and then on to Antarctica for the Dec. 4, 2021, total solar eclipse. I'll be proud to report on the activities of *Astronomy* magazine's tour group in an upcoming issue. We'll catch 44 seconds of the Moon blocking the Sun in one of the most exotic locales on the planet.

I've been fortunate to see quite a few solar eclipses, even though my first love has always been deep-sky objects — clusters, nebulae, and galaxies. Nonetheless, solar eclipses bring something very special. When the inevitable approach of the Moon to the Sun's disk blocks out daylight, the situation becomes almost spiritual. Seeing the geometry of the solar system align so precisely, right on cue, gives rise to emotions in many first-time viewers. I've seen people cry, dumbfounded, in the eclipse path.

An even bigger event is coming to the United States in 2024. The total eclipse two years from now will swing northeastward from Mexico through Texas, the Ohio Valley, and up the Eastern Seaboard. In its path live more people than have ever witnessed a single eclipse before. This event will no doubt be the most-viewed eclipse in history — that is, unless the whole United States is clouded out. (Shame on me for even bringing that up!)

Michael E. Bakich's story "First look at the 2024 total solar eclipse" (page 24) provides all you'll need to know to plan for this majestic event. Michael is an experienced and keen eclipse-chaser, and an authority on the subject. The practical advice, maps, predictions, and how-to observing tips in this story will set you up well for viewing a grand event that you will absolutely not want to miss. Not even a deep-sky guy wants to do that.

Get ready soon. It's never too early to plan for a spell in the shadow of darkness.

Yours truly,

David J. Eicher
Editor

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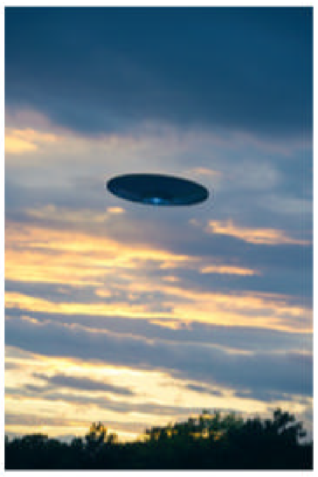
People have speculated about the existence of UFOs for many generations, as illustrations like this suggest. UFO © EMOKE KUPAI/DREAMSTIME

Earth-bound

In David J. Eicher's Editor's Note in the October issue, he said, "It may well be that reports of UFOs tell us more about the nature of people here on our planet rather than any potential advanced life forms that may exist in deep space." I have felt for some time that any UFOs, whether they are real piloted technological objects or some mystical creation, might be related to our Earth. We know so little of our home planet and all that pertains to it. **—William Arthur,** Highlands Ranch, CO



A bit dusty

After reading Bob Berman's article "Dust to dust" in the September issue, I wanted to ask a tongue-in-cheek question of Bob: Just how filthy is your bedroom? In the article, Bob states that dust in the air of a bedroom settles at the rate of 1 inch an hour. Now, I don't end up with 2 feet of dust on my bedroom floor and furniture every day, so I'm just looking for clarification. Does he mean that if you took the entire dust content of a typical bedroom for an hour it would fill some type of gauge, akin to a rain gauge measurement, to a depth of 1 inch? **—John A. Ferko,** Colorado Springs, CO

Author Bob Berman responds:
Fortunately, no, my bedroom is not covered with many inches of dust. Or any dust at all that I can see. Yet that "inch an hour" is the oft-published figure for the speed of settling airborne dust. My guess is that people's and pets' motions, and air currents from windows or heating systems, constantly cause dust to circulate and even rise from furniture, floors, and such, so it's a continual process.

We welcome your comments at Astronomy Letters, P.O. Box 1612, Waukesha, WI 53187; or email to **letters@astronomy.com***. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

A round of applause

Brava, Ms. Buongiorno, on the beautifully written article on neutron stars. Your prose is clear and concise and a pleasure to read! **—Kathleen Dusto**

SNAPSHOT

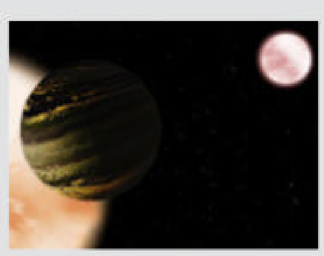
MYSTERY: SUPERBUBBLE

N44 has a strange hole at its heart.

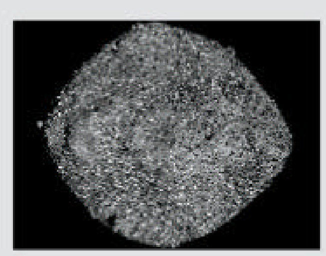
Lurking approximately 170,000 light-years away within the Large Magellanic Cloud is the nebula N44. This cosmic gem is notable not for its structural complexity, massive stars, or glowing hydrogen gas, but for its hollowed-out core. Some 250 light-years wide, the hole, called a superbubble, is a cosmic enigma.

One theory for the superbubble's presence is that stellar winds from massive stars at its core may have blown away the gas. But the winds aren't fast or powerful enough to account for this. Another theory points to the nebula's population of massive stars, which age quickly and end their lives in supernovae. A series of such stellar explosions and their expanding debris shells could have carved out the gaping wound within N44. However, only one supernova remnant has been identified inside the superbubble so far, leaving the hole an open mystery. —CAITLYN BUONGIORNO

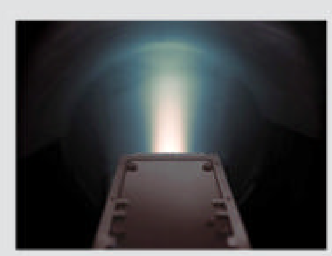
HOT BYTES



TWO-FOR-ONE
A new technique lets the exoplanet-hunting TESS mission identify a planet circling a binary system after only two transits (one for each star). That's one less stellar crossing than was previously required.



BIG ROCKS
NASA's OSIRIS-Rex spacecraft found that asteroid 101955 Bennu is covered in larger rocks than expected. Scientists say the highly porous rocks withstood impacts better than denser rocks, becoming compressed rather than fragmented.

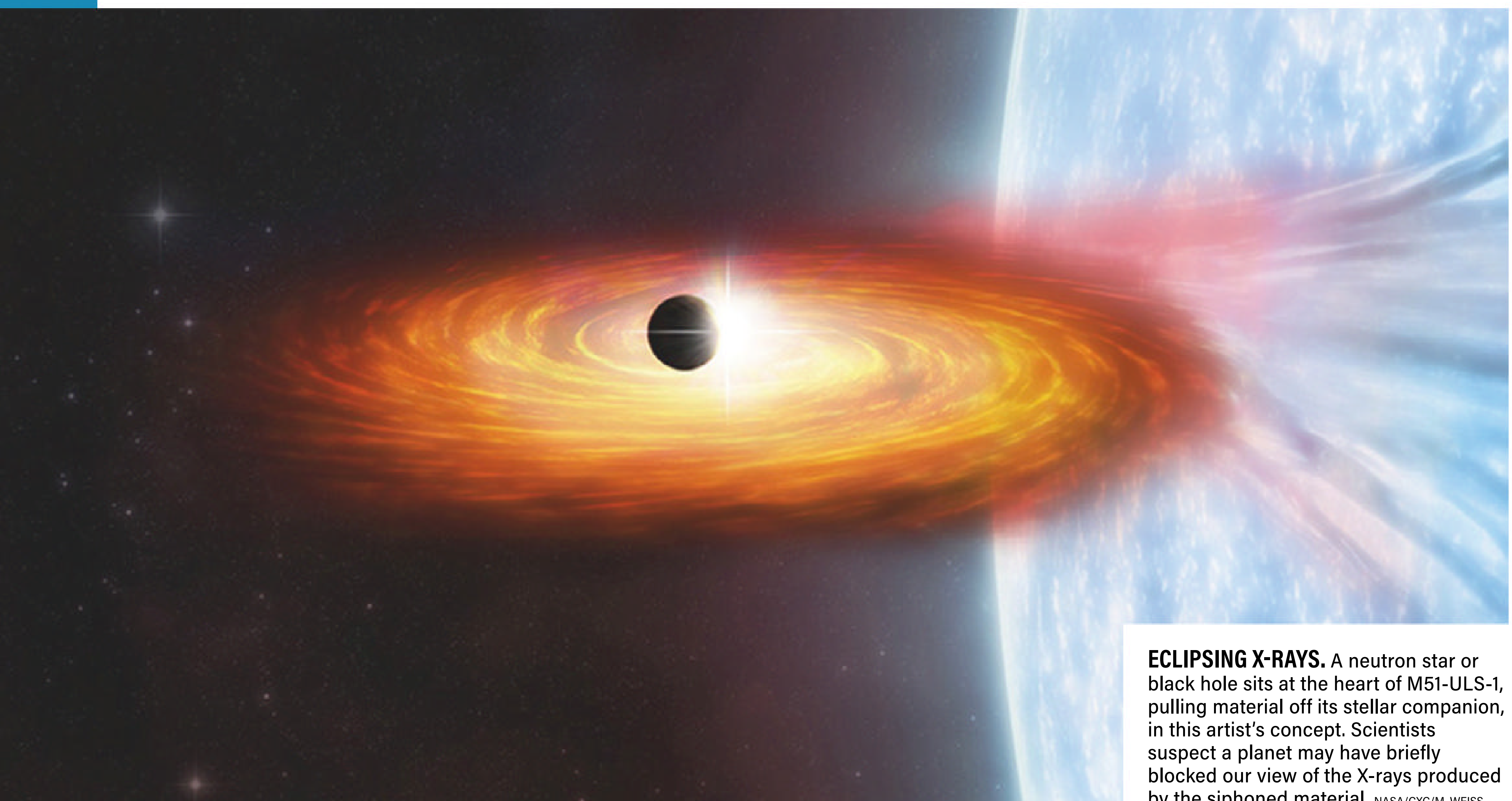


ALTERNATIVE FUEL
A newly developed electric rocket engine expels iodine as a propellent to create thrust. Iodine is cheaper, safer, and easier to store than the xenon currently used in such engines.

NASA, ESA, V. KSOLL AND D. GOULIERMIS (UNIVERSITÄT HEIDELBERG), ET AL.; PROCESSING: GLADYS KOBER (NASA/CATHOLIC UNIVERSITY OF AMERICA). BOTTOM FROM LEFT: PSI/PAMELA L. GAY; NASA/GODDARD/UNIVERSITY OF ARIZONA; THRUSTME

AN EXOPLANET OUTSIDE THE MILKY WAY?

In a galaxy far, far away may lie an exoplanet circling a binary system.



ECLIPSING X-RAYS. A neutron star or black hole sits at the heart of M51-ULS-1, pulling material off its stellar companion, in this artist's concept. Scientists suspect a planet may have briefly blocked our view of the X-rays produced by the siphoned material. NASA/CXC/M. WEISS

» Astronomers think they may have spotted the first extragalactic exoplanet — a planet outside of our own galaxy.

Residing some 28 million light-years away in the Whirlpool Galaxy (M51), the binary system M51-ULS-1 consists of either a neutron star or a black hole paired with a more ordinary companion star 20 times the mass of the Sun.

Evidence for this possible planet came from X-ray data rather than the visual light observations astronomers usually use to detect exoplanets. "We are trying to open up a whole new arena for finding other worlds," said study lead Rosanne Di Stefano of the Harvard-Smithsonian Center for Astrophysics in a press release.

The new research, published Oct. 25 in *Nature Astronomy*, examined three galaxies: M51, M101, and M104. The team targeted more than 200 star systems within these galaxies, using the Chandra X-ray Observatory and the European Space Agency's XMM-Newton. Within all those systems, they found only one potential exoplanet.

HUNTING EXOPLANETS

Researchers have mainly used two methods to spot the Milky Way's more than 4,000 confirmed exoplanets so far. The radial velocity method measures how a star slightly wobbles as an orbiting planet gently tugs on its stellar host. Alternatively, the transit method spots planets that cross in front of their stars, which briefly dims the starlight we detect.

The transit method has been the most useful, spotting planets out to about 3,000 light-years from Earth — well within the boundaries of the Milky Way, which is 100,000 light-years across. To find extragalactic planets, scientists tried searching for transiting planets within X-ray binaries. These systems contain a white dwarf, neutron star, or black hole pulling in material from a companion star. As this material falls into the remnant's accretion disk, it becomes superheated, producing X-rays.

In these binary systems, the specific area where X-rays are produced within the accretion disk is tiny enough that even a planet can block a significant portion (if not all) of the X-ray light. This makes X-ray transits detectable at much greater distances than visual transits.

In the case of M51-ULS-1, the system

NASA, ESA, AND R. SAHAI (JET PROPULSION LABORATORY); PROCESSING: GLADYS KOBER (NASA/CATHOLIC UNIVERSITY OF AMERICA)

Incredible frEGGs

Each of these tadpolelike blobs of cold, dense gas is incubating newborn stars deep inside it. These objects — imaged here by the Hubble Space Telescope and located in the Northern Coalsack Nebula in Cygnus — are known as free-floating Evaporating Gaseous Globules, or frEGGs. They are the surviving remnants of a much larger cloud of gas that has been steadily evaporating, heated by ultraviolet radiation from nearby stars. Similar structures, called Evaporating Gaseous Globules, or EGGs, were first spotted in the famous "Pillars of Creation." In that iconic Hubble image, the EGGs appear as dark, elongated tendrils protruding from the larger gas pillars in the Eagle Nebula (M16). But the Northern Coalsack's frEGGS are being heated from multiple directions, effectively pinching them off from the main cloud and leaving them as free-floating structures. —MARK ZASTROW

SPIRAL HOME. Nestled inside one of the Whirlpool Galaxy's arms lies M51-ULS-1, at a distance of more than 28 million light-years away. X-RAY: NASA/CXC/SAO/R. DISTEFANO, ET AL.; OPTICAL: NASA/ESA/STSCI/GENDLER

is one of M51's brightest X-ray binaries. But when astronomers examined Chandra data, they saw that for three hours, the X-rays emanating from the system dropped to 0. According to the researchers, this suggests that a Saturn-sized exoplanet is orbiting the binary system at some 19.2 astronomical units (AU; where 1 AU is the average distance between Earth and the Sun). That's about twice as far as Saturn is from the Sun.

However, an exoplanet isn't the only explanation for why the X-ray signal could have been disrupted. X-ray sources can also be obscured by a cloud of dust passing in front of them. The researchers did consider this explanation, too, but ultimately concluded it was less likely than an exoplanet.

Unfortunately, confirming the extragalactic detection will take a long time. With such a wide orbit, the candidate isn't expected to pass in front of the source again for another 70 years. —C.B.

QUICK TAKES

LAUNCH AND REPEAT

This year, South Korea will begin developing a reusable rocket equipped with a cluster of liquid-fueled, 100-ton-thrust engines. With a starter budget of $10.2 million, the government intends for the new rocket program to dramatically slash launch costs.

EXO-ATMOSPHERE

In a first, astronomers have measured the abundance of both water and carbon monoxide in the atmosphere of an exoplanet, WASP-77Ab. The team used the ground-based Gemini Observatory in Chile, which provided clearer data than the Hubble Space Telescope.

ARTEMIS 2025

NASA announced Nov. 9 that the Artemis program's first lunar landing won't occur until at least 2025 due to budgetary constraints, COVID impacts, testing delays of the Space Launch System rocket, and extended litigation over the Human Landing System contract.

INFANT PLANET

The newly found exoplanet 2M0437b is one of the youngest planets yet known. The budding world likely formed within the past several million years — roughly when the Hawaiian Islands emerged from the Pacific Ocean.

DEEP RED SPOT

New data from NASA's Juno spacecraft show that Jupiter's Great Red Spot — a centuries-old vortex wider than Earth — extends even deeper than previously thought, plunging more than 200 miles (350 kilometers) beneath the world's chaotic cloud tops.

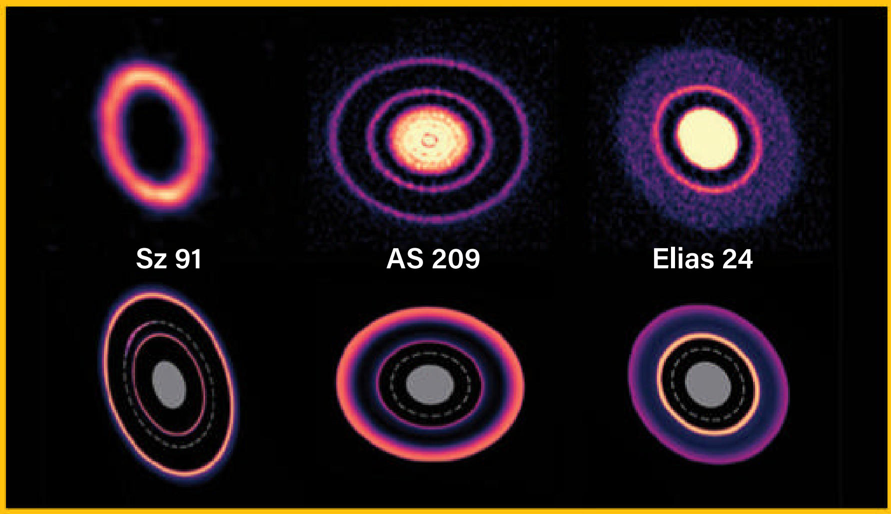
JWST + EHT = SGR A*

NASA's James Webb Space Telescope (JWST) will join the Event Horizon Telescope (EHT) to image the Milky Way's supermassive black hole, Sagittarius A* (Sgr A*). Scientists hope the infrared view, which cuts through intervening dust, will provide insight into Sgr A*'s flickering flares. —JAKE PARKS

DISAPPEARING RINGS

The Atacama Large Millimeter/submillimeter Array (ALMA) often observes dusty protoplanetary disks circling young stars. And a pattern that continues to emerge in ALMA images is rings and gaps within these disks. One theory for how such features form is that budding planets carve out gaps as they accumulate material, pushing uncaptured dust grains to the outer edge of the gap to create a ring. To test this scenario, astronomers have begun seeking planets near the rings they've presumably sculpted — starting with the outer rings, which are easier to observe because they are less likely to be lost in the glare from the host star. But so far, these observations have turned up nothing.

Researchers recently explored the mysterious origins of rings by simulating how a migrating planet affects the rings of a protoplanetary disk, using the most powerful supercomputer dedicated to astronomy: ATERUI II at the National Astronomical Observatory of Japan in Oshu. Their results show that, at least in



STEP BY STEP. The three phases of ring formation, from left to right, are shown here. The top row highlights ALMA examples of each simulated phase, while the bottom row comprises ATERUI II simulations. The gray regions in the simulated views were not calculated by the supercomputer; the dotted lines show the planet's orbit at each stage of the simulation. KAZUHIRO D. KANAGAWA, ALMA (ESO/NAOJ/NRAO)

Black hole's gravity gives it away

Black holes, as their name suggests, give off no light of their own, making them notoriously difficult to detect. But often, black holes appear in binary systems with a normal star. In these cases, the gravitational pull of the black hole on its visible companion may be the only sign of its presence.

That's exactly what researchers saw within NGC 1850, a cluster of stars some 160,000 light-years away in the Large Magellanic Cloud. They used the Multi Unit Spectroscopic Explorer on the Very Large Telescope in Chile; this instrument allows astronomers to look closely at the light of individual stars — even those packed within the distant, crowded cluster. By doing so, scientists discovered an invisible member: a black hole 11 times the mass of our Sun, causing noticeable motion in a visible star five times the mass of the Sun.

INVISIBLE PARTNER. Within the extragalactic star cluster NGC 1850 is a binary system containing a black hole and a massive star. This artist's concept shows how the gravitational pull of the black hole distorts its companion's shape; that same influence also tugs on the star's orbit. ESO/M. KORNMESSER

The research, published Nov. 11 in *Monthly Notices of the Royal Astronomical Society*, is the first time scientists have found such a small black hole in another galaxy using only its gravitational influence. The researchers say this type of gravitational, or dynamical, influence is the best way to spot many stellar-mass black holes, which have masses up to about 100 times that of the Sun. That's because other methods for finding these objects require the black hole to be actively feeding or in the throes of smashing into its partner.

What's more, NGC 1850 is relatively young — just 100 million years old. In such young clusters, it's even less likely that black holes will be feeding or colliding, making dynamical interaction the only technique available to find them in such environments. So, targeting young clusters using this method is an opportunity to increase the known number of younger stellar-mass black holes. Astronomers can then compare them to older black holes found via other methods to study the life cycle of these extreme objects. —ALISON KLESMAN

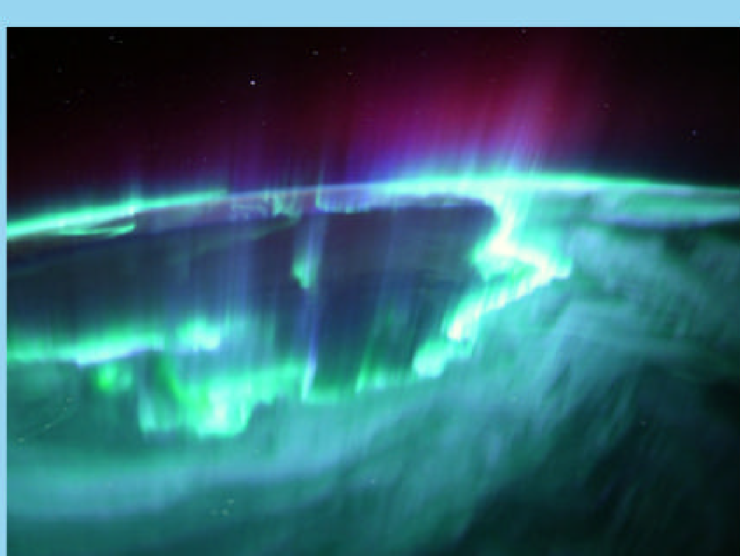
a low-viscosity (easy to move through) disk, three distinct steps occur.

First, a ring forms just outside the original location of the planet and the world eventually migrates inward. Next, that initial ring (still at its original location) begins to deform and a second ring starts to materialize near the new location of the migrated planet. According to the study, published Nov. 12 in *The Astrophysical Journal*, these two rings can coexist for more than a million years. Finally, the outer ring fully dissipates, leaving behind only the inner ring.

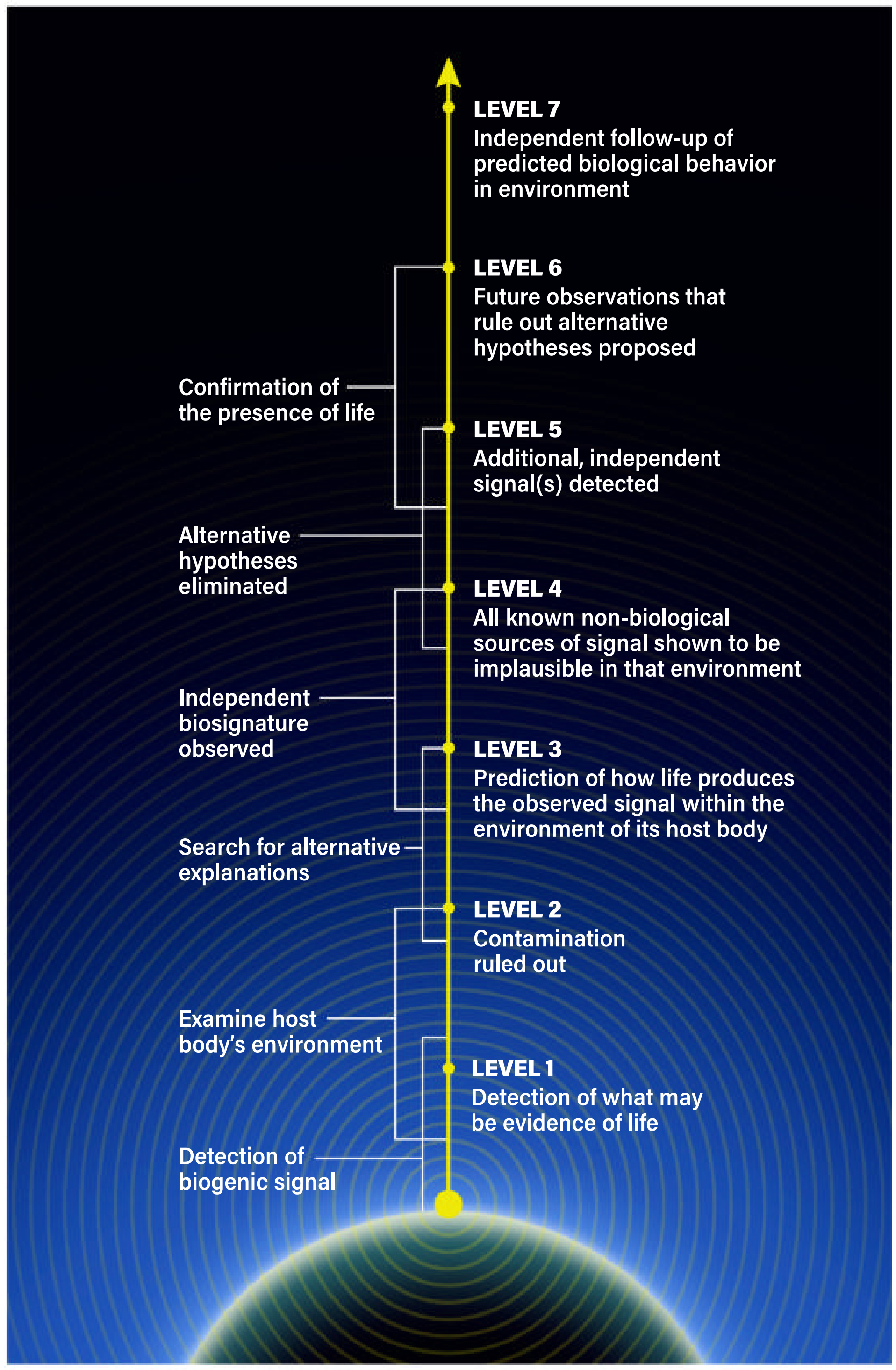
Moving forward, more-capable, next-generation telescopes will be able to better search for planets near the inner rings of numerous protoplanetary disks, confirming whether or not these new simulations really mirror reality. –J.P.

Strong aurorae dazzle astronauts

In late October, an intense flare erupted from the Sun. A few days later, European Space Agency French astronaut Thomas Pesquet captured this stunning light show from aboard the International Space Station as the station passed over North America. Pesquet's description, posted on his Flickr account, reads, "We were treated to the strongest auroras of the entire mission, over north[ern] America and Canada. Amazing spikes higher than our orbit, and we flew right above the centre of the ring, rapid waves and pulses all over." Aurorae occur when waves of charged particles from the Sun strike Earth's magnetic field, causing atoms in the atmosphere to glow. Studying space weather, including aurorae and other effects, can help us better understand our Sun and the dangers such outbursts could pose to future astronauts. –A.K.



ESA/NASA-T. PESQUET



ASTRONOMY: ROEN KELLY, AFTER GREEN, J., HOEHLER, T., NEVEU, M. ET AL.

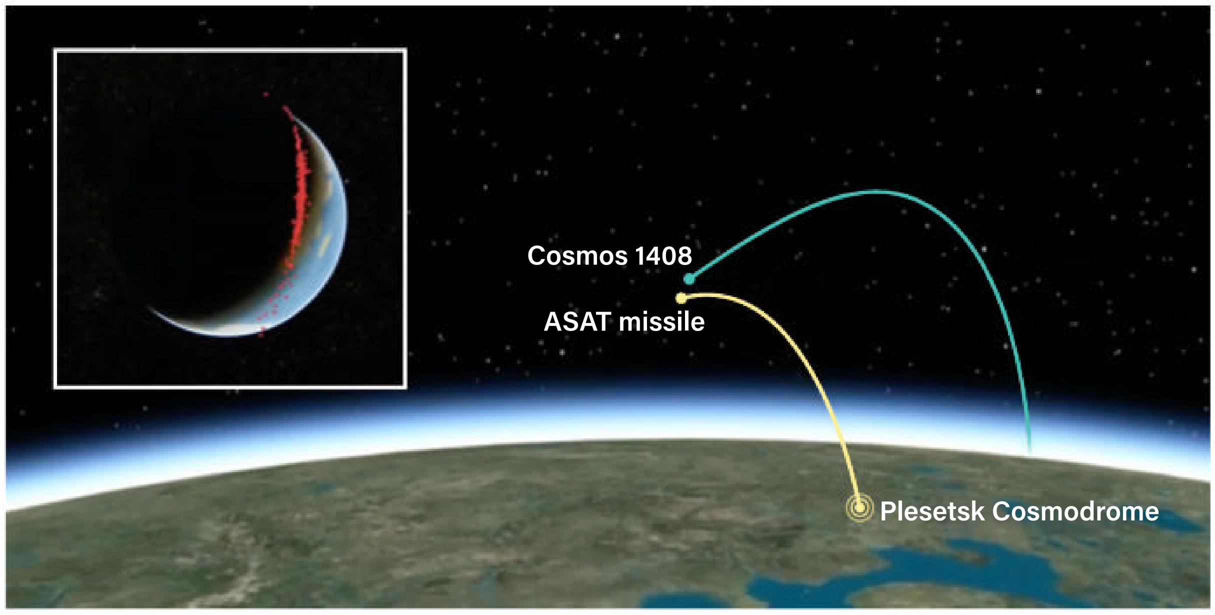
HOW TO ANNOUNCE ALIENS RESPONSIBLY

It's alive. Orson Welles' infamous 1938 radio broadcast of "The War of the Worlds" provides some clues about how announcements of alien life can quickly get out of hand. While the first real report of alien biosignatures is doubtful to be anything like people-snatching alien tripods, it is important that the messaging is handled properly. A recent essay published Oct. 27 in *Nature* proposes a scale for communicating the strength of evidence for life beyond our planet. The scale starts with the initial detection, clearly defining a set of follow-up observations that must be taken to confirm the presence of life and rule out alternative explanations. –C.B.

FAST FACT

Another study, published in 2020 in *The Astrophysical Journal*, suggests that a minimum of 36 communicating civilizations could exist in the Milky Way.

RUSSIA CARRIES OUT ANTI-SATELLITE TEST



INTERCEPTION. The direct-ascent missile that took out Cosmos 1408 followed an arcing path to strike the satellite, as depicted in this simulation. The inset shows how the cloud of debris created by the impact quickly stretched out after completing just one orbit. Eventually, the particles will be scattered roughly evenly over the whole globe. EUROPEAN UNION SPACE SURVEILLANCE AND TRACKING

» Russia destroyed one of its own satellites in a test Nov. 15, creating a cloud of debris that prompted astronauts and cosmonauts on the International Space Station (ISS) to briefly shelter in docked return capsules.

In the test, a missile was launched from the Plesetsk Cosmodrome and struck Cosmos 1408, a defunct intelligence satellite orbiting between 289 miles (465 kilometers) and 304 miles (490 km) high. U.S. Space Command reported the anti-satellite (ASAT) test generated over 1,500 pieces of detectable orbital debris and likely created hundreds of thousands of smaller, undetectable pieces.

Such tests have always drawn scrutiny: As the amount of orbital debris grows, so does the risk of catastrophic collisions with other satellites or crewed spacecraft. According to an analysis by the space tracking company LeoLabs, the Russian test may have increased the density of debris at 250 miles (400 km) — a typical altitude of the ISS and China's Tiangong space station — by more than three times.

LeoLabs noted that the choice of satellite made this ASAT test particularly risky. Cosmos 1408 was in a high-inclination orbit, passing close to Earth's poles on a path that intersects with almost every other orbit at the same altitude. That altitude is also crowded orbital space — less than 62 miles (100 km) above the ISS and Tiangong and less than 62 miles (100 km) below many commercial satellites, including SpaceX's Starlink constellation.

In an ASAT test, the impact kicks debris into higher and lower orbits. In this case, most of the debris pushed into lower orbits will reenter the atmosphere within five years, LeoLabs said. But debris boosted into higher orbits may take decades to reenter.

The test drew swift reproach from U.S. and European officials. U.S. Secretary of State Antony J. Blinken called the test "recklessly conducted" and "dangerous and irresponsible." The European Union's internal market commissioner, Thierry Breton, condemned the test, adding the event was "a reminder that space is increasingly contested."

NASA Administrator Bill Nelson said he was "outraged by this irresponsible and destabilizing action. With its long and storied history in human spaceflight, it is unthinkable that Russia would endanger not only the American and international partner astronauts on the ISS, but also their own cosmonauts."

Russian officials called U.S. criticism hypocritical, pointing out the U.S. has also conducted ASAT tests. The most recent U.S. ASAT demonstration was in 2008. It targeted a satellite in a lower orbit than the Russian test — as did an Indian test in 2019 — resulting in shorter-lived debris.

China performed an ASAT test in 2007 against a satellite roughly 530 miles (850 km) high. That created a long-lived debris cloud: The week before Russia's test, the ISS was forced to maneuver to avoid a piece of it. – M.Z.

Hubble's catch of the day

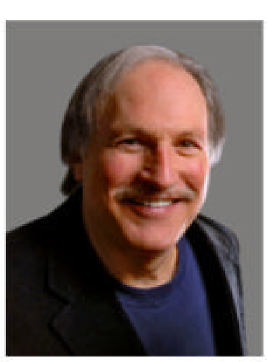
Some 6,000 light-years distant lies the Prawn Nebula (IC 4628), a massive stellar nursery within the constellation Scorpius. IC 4628 is an emission nebula, meaning its gas is energized thanks to radiation from nearby stars. The energy it absorbs is then re-emitted in the form of infrared light. Unfortunately, despite spanning some 250 light-years and taking up the equivalent of four times the size of the Full Moon in our sky, the nebula is all but invisible to our sight because the human eye can't detect this type of light. Thankfully, the Hubble Space Telescope's Wide Field Camera 3 *can* pick up on this glow, giving astronomers the opportunity to peer into the deep cosmic sea to study objects like the Prawn. – C.B.

NASA, ESA, AND J. TAN (CHALMERS UNIVERSITY OF TECHNOLOGY); PROCESSING; GLADYS KOBER (NASA/CATHOLIC UNIVERSITY OF AMERICA)

When astronomers get stuck

Here's some trivia to enjoy the next time you hit traffic.

If taillights are all you can see on your next summer road trip, this column can offer some help to pass the time. DISQDR/DREAMSTIME



BY BOB BERMAN
Bob's recent book, Earth-Shattering *(Little, Brown and Company, 2019), explores the greatest cataclysms that have shaken the universe.*

As the weather improves, we astronomers get the itch to jump in our cars and travel, just like everyone else. And get stuck in traffic. As boredom threatens, we might seek refuge in traditional roadway games.

One popular pastime is observing license plates. So, guess how many states' tags contain a celestial image? Surprise: several!

Texas' standard plate shows its trademark lone star. Colorado's is dominated by what I imagine to be a huge unspoiled night sky above white mountains. Kansas' spells out its Latin state motto, "*Ad astra per aspera*," which is also the oath its astronomers repeat after dropping their costliest eyepiece: "To the stars through difficulties." Still others — Arizona's, Ohio's, South Carolina's — portray the Sun or Moon. And Alaska offers specialty plates featuring the aurora or the same star pattern as its flag: the Big Dipper pointing to Polaris.

But let's get to real science. Once you've exhausted the parade of license plates, move on to observing your surroundings. Look out your car window and notice whether the horizon is dark blue, light blue, or milky. When you peer toward the low sky, you're sighting through 40 times more air than when you look high overhead. Each tiny water droplet in that air scatters sunlight, creating a whitening effect. In bone-dry places like the southwestern U.S., the air's minuscule moisture keeps the horizon blue. In humid locales like the Carolinas, the low sky is creamy. A deep blue low sky means the dew point is below 40 to 50 degrees Fahrenheit (4 to 10 degrees Celsius) — desertlike aridness. Pale blue indicates a dew point around 60 F (16 C). Milkiness with no blue reveals a dew point above 70 F (21 C), meaning you'll see very few stars that night. Check your humidity appraisal against the local weather service. You'll get good at this fairly quickly.

Next up, pull out your sunglasses, because it's time to discuss polarization. Air molecules scatter sunlight, causing the rays to march in unison at a point about 90° from the Sun and syncing up the solar electric field vectors. This makes the sky surrounding that spot — just where the half Moon floats — the deepest blue of the whole sky when you've got your polarizing sunglasses on. Go ahead, take a look.

Trivia is another popular highway pastime. First, some plain old physics trivia. We can stump your geekiest passenger. Ask them to guess the minimum driving speed that causes bugs to splatter on windshields. It's about 38 mph (61 km/h). Stay slower than that and you'll make it home from a car wash with the car still gleaming, because insects just bounce off, intact.

It's easy to add auto safety to our road trip trivia game. Just as with the asteroid impacts that cause mass extinctions and lunar craters, speed is far more critical than a moving object's weight. Hopefully you'll never validate this kinetic energy principle by totaling your car, but if that seems imminent, be aware that a crash at 35 mph (56 km/h) is twice as damaging as one at 25 mph (40 km/h). That amazing stat means even a small velocity decrease before an abrupt stop helps enormously. So brake hard.

Road trips can be real catnip for science lovers.

Expand the conversation by considering a 2009 *Universe Today* article stating that about 1 percent of the static between FM channels is leftover microwave noise from the Big Bang. Can you therefore prove the Big Bang theory while stuck in traffic? It's gotten trickier. About a decade ago, most broadcasters switched from analog to static-free digital, and that meant bye-bye to Big Bang signals. But if you drive an older car — I still adore my 2005 Solara convertible — then your analog radio may still keep you in business. When trapped in traffic, you're also stuck in an expanding universe, and an old car may help prove it.

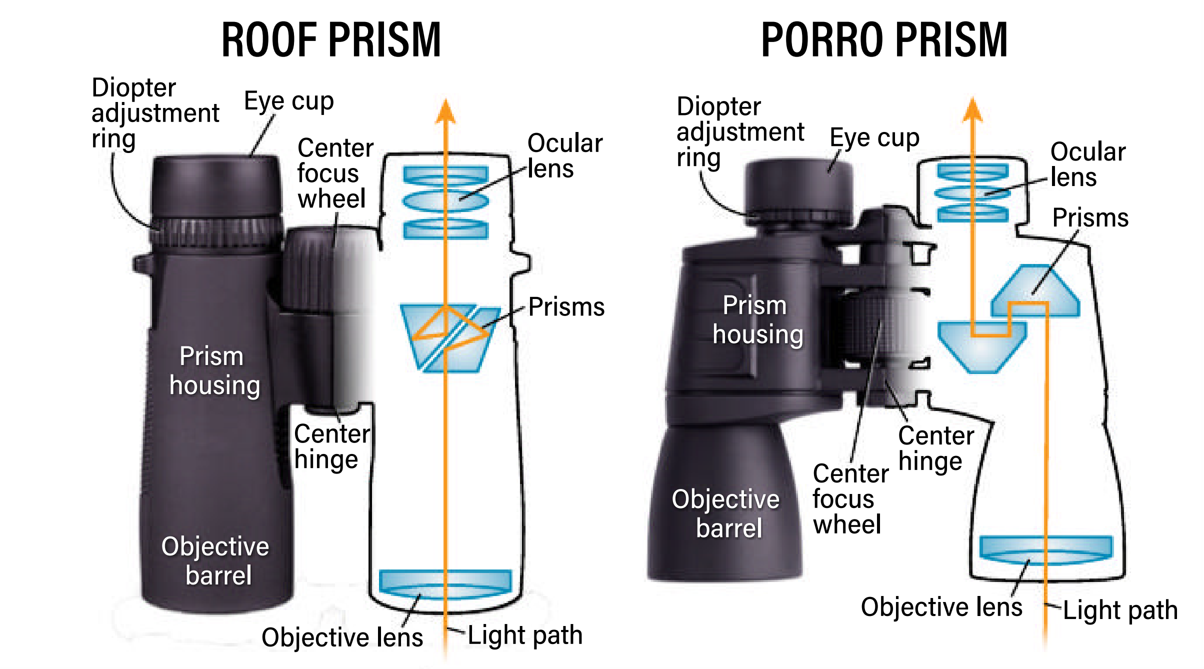
Road trips can be real catnip for science lovers. But — perhaps to make you consider that next turnoff — your overall lifetime odds of dying in a car as of 2019: 1 in 107. That's very similar to the chance of not making it back from a space shuttle launch, back when they still flew.

You knew we'd get back to astronomy sooner or later.

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman**

Binocular basics

It's the easy way to enhance your view of the cosmos.



Because the prisms in roof prism binoculars are in line, they are easier to hold. But the offset prisms of Porro prism binoculars often provide a wider field of view and greater depth of field than comparable roof prism models.
ASTRONOMY: ROEN KELLY

If you honed the skills I described in last month's column, you have a general idea of what's up in the evening winter sky. But by now, you're dying to explore the heavens above with a telescope. And I won't hold you back. In fact, you're going to use two telescopes! But not quite how you think: I'm talking about using a "dual wide-field refractor," more commonly known as binoculars.

"Wait a minute," you say. "Why not a real telescope? One that magnifies a gazillion times so I can really explore outer space?"

I'll admit, that was my attitude when I first got interested in amateur astronomy; I bypassed binoculars in favor of a telescope. However, I soon discovered that not all celestial objects require great magnifications to enjoy. In fact, such power can sometimes be detrimental. Case in point: Large star clusters like the Pleiades and Hyades were too expensive to fit inside the limited eyepiece field of my scope. I needed optics capable of bridging the gap between unaided eye and telescope. This is why I purchased a pair of 7x50 binoculars. (The first number is the magnifying power, while the second number is the diameter of the objective lenses in millimeters.) In doing so, I opened a whole new window to the universe.

If you're in the market for binoculars, here are the basics. Each barrel is a low-power, wide-field refracting telescope with internal prisms that serve to undo the upside-down image produced by astronomical refractors. Binoculars come in two main designs: roof prism and Porro prism. The latter option is preferred for astronomy, partly because it allows more light to reach the eyes. Fully coated optics and prisms made of BaK4 (barium crown) glass also enhance the view.

Of the many sizes available, 7x50 binoculars are generally the go-to for astronomical observing. Binoculars with only a center focus don't take into consideration the different visual capabilities of each eye. However, binos that combine center focus (both barrels simultaneously) with the ability to make so-called diopter adjustments (each barrel individually) allow you to tailor the focus finely to each eye.

So, are you ready to put your two pocket telescopes to work? If it's clear tonight, grab a pair of binoculars and head outside. As you did last month, bring along a red-filtered flashlight and this copy of *Astronomy*, turned to the Star Dome map on page 34. If your horizon is open to the west and southwest, you can still catch a glimpse of the constellations we explored last month. Begin with Orion's Belt and Sword, an area alive with stars. That fuzzy patch within the Sword is the Orion Nebula (M42), and binoculars help bring out its beauty. Next, catch the Pleiades above the western horizon before moving on to the Hyades, the V-shaped cluster that forms the head of Taurus the Bull. The Hyades overcrowds the tight field of a telescope, but it comfortably fits inside a wide, low-power binocular field. Also seek out the Beehive Cluster (M44) in Cancer the Crab, then sweep the area from the foot of Gemini the Twins through the middle of Auriga the Charioteer to see if you can spot the four fuzzy forms of open clusters M35, M36, M37, and M38.

So, are you ready to put your two pocket telescopes to work?

For a real challenge, aim your binos at Gamma (γ) Ursae Majoris in the bowl of the Big Dipper. Move diagonally across the bowl to Alpha (α) and continue an equal distance beyond. If skies are dark enough, you should stumble across two small hazy patches — one round, one elongated. These are galaxies M81 and M82, located some 12 million light-years away. See, you don't need a gazillion-power telescope to explore the distant cosmos!

Want more? Two *Astronomy* columnists have penned guidebooks for the binocular user. Stephen James O'Meara is the author of *Observing the Night Sky With Binoculars* (Cambridge University Press, 2008) and Phil Harrington wrote *Touring the Universe Through Binoculars* (Wiley, 1990). Harrington also puts together the Binocular Universe column in each issue of *Astronomy*. As he often advises, remember that two eyes are better than one.

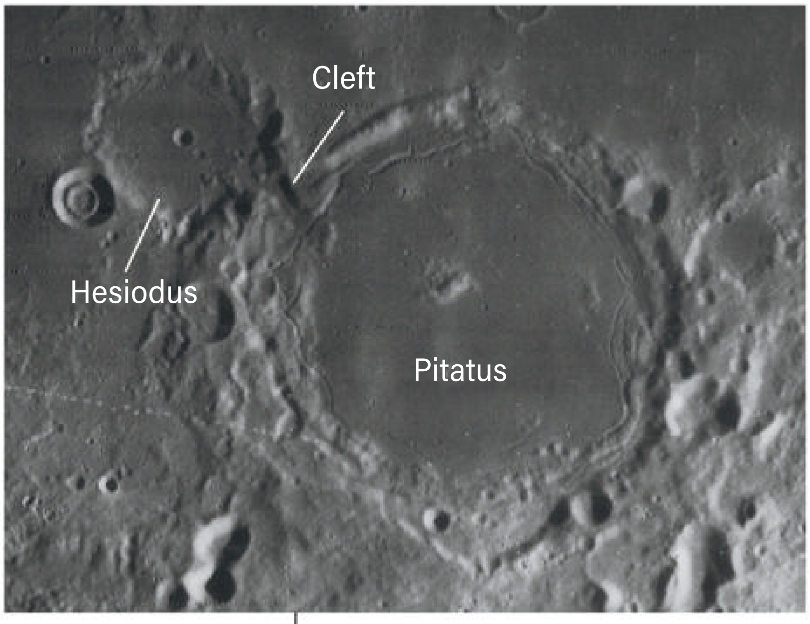
Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: choosing your ideal first telescope. Clear skies!

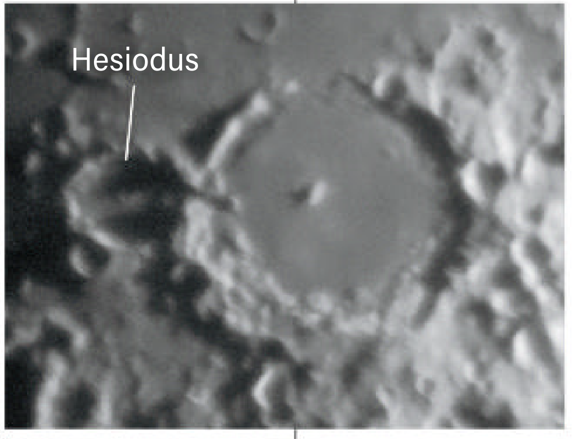
BY GLENN CHAPLE
Glenn has been an avid observer since a friend showed him Saturn through a small backyard scope in 1963.

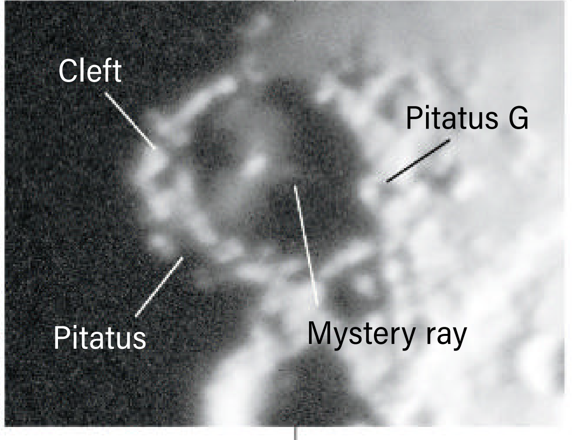
BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple**

Lunar morning magic

Daybreak on the Moon makes for spectacular sights.







CLOCKWISE FROM TOP LEFT: This Lunar 4 Orbiter image of Pitatus shows the cleft in the northwest wall leading into Hesiodus. NASA/USGS/LPI

The Hesiodus ray was imaged through the author's 3-inch Tele Vue refractor May 20, 2021. STEPHEN JAMES O'MEARA

The mystery ray in Pitatus, taken through the author's 3-inch refractor on the night of April 20, about 12 hours and 45 minutes after First Quarter. STEPHEN JAMES O'MEARA

BY STEPHEN JAMES O'MEARA
Stephen is a globe-trotting observer who is always looking for the next great celestial event.

Sunrise can be magic — even on the Moon. One prime example lies in Mare Nubium (Sea of Clouds), where the lunar crater Pitatus and its smaller neighbor, Hesiodus, sink into its southern floor like lunar lagoons. And like their earthly counterparts, these lagoons have enchanting elements.

Named after Italian astronomer Pietro Pitati, the crater Pitatus formed some 4 billion years ago. It was later flooded by molten rock seeping through cracks in the crater's shallow floor.

Even the smallest of telescopes will show a wide gash — a fault line — ripping through the crater's northwest wall, which is shared with 28-mile-wide (45 km) Hesiodus crater. And at this site, sunrise magic can occur.

We can see Hesiod being born from a ray of light, just as night ends and day begins.

Born from light

A near contemporary of Homer, the Greek poet Hesiod, namesake of the crater Hesiodus, believed that the Muses — the nine daughters of Zeus and Mnemosyne, inspirational goddesses of the arts and sciences — filled him with the light of poetry. And in his *Theogony* (meaning "birth of the gods"), we see how darkness gives birth to light: "Night, pregnant after sweet intercourse with Erebos [the primordial god of darkness], gave birth to … Day."

Thanks to the gap in the shared crater wall of Pitatus and Hesiodus, when dawn breaks at that location, we can see Hesiod being born from a ray of light, just as night ends and day begins. It is one of the many fascinating sights on the Moon, but you have to catch it at just the right time to receive its full impact.

The Pitatus "gateway" opens about the eighth or ninth day after New Moon, when sunlight slips through the shared cleft — more like a valley — in the crater wall. This creates a spectacular shaft of light across the crater's shadowed floor. Two weeks later, the reverse happens, with a sunset ray filtering through the cleft to create a narrow light ray slicing eastward across the floor of Pitatus. Philip Koch of Las Vegas popularized the phenomenon, which he first saw in 1988.

Another ray

On the evening of April 20, 2021, the Moon achieved First Quarter. While it was too early to see the Hesiodus ray, I decided to check in on southern Mare Nubium with my 3-inch Tele Vue refractor. I was not disappointed.

While Hesiodus was completely immersed in shade, Pitatus hugged the terminator, offering an eye-catching interplay of light and shadow. It wasn't long before the view baffled me: Beaming across its flat floor was a narrow ray that broadened slightly toward the crater's sunlit central peak — splitting the long shadow of Pitatus's eastern wall in two.

While this ray was a poor cousin to the Hesiodus ray, it warrants attention. Perhaps it is created from some topographical depression in or near the crater Pitatus G, a smaller crater on the rim of Pitatus. The image above was taken through my 3-inch scope, and it does not do the clarity of the feature justice. It looked at first like an illuminated walkway reaching from Pitatus G to the shining monolith that is Pitatus' central peak. I then noticed lunar ray material north and south of the peak also spreading out across the floor like wings, giving it a birdlike quality.

At the time of my observation, the Moon was 57 percent illuminated and 8.1 days old. The Sun's colongitude was 14°, meaning the selenographic (lunar) longitude of the morning terminator was –14°. This month, a similar, but not exact, circumstance occurs March 11 at 14:30 UT, when the Moon will be 61.2 percent illuminated and 8.4 days old, with a colongitude of 14°. Will the sunrise ray in Pitatus reappear?

By the way, the sunrise ray in Hesiodus may occur about seven hours and 15 minutes later. As always, send your observations to sjomeara31@gmail.com.

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara**

WILD WEATHER OF THE

Today's forecast: scalding temperatures, extreme winds, and a chance of diamond downpours.

The solar system whips up some wild weather — from Jupiter's newly discovered stratospheric winds, to Neptune's recent giant storm reversal, to Titan's methane floods. But while the Coriolis effect, polar jets, cyclones, and precipitation may switch things up a bit, all planetary weather relies on the same basic ingredients we have here on Earth: atmosphere, heat transfer, and planetary tilt and spin.

Atmosphere gives body to winds. Heat flux fuels those winds. And planetary spin curves them, planting the seeds for cyclones or vortices. Hotter, rising air fosters low-pressure cells, while colder, descending air creates high-pressure systems. On Earth, this all translates to phenomena such as trade winds, jet streams, hurricanes, monsoons, and a mélange of other weather. Elsewhere, the recipes become more exotic and extreme.

THE ROCKY PLANETS

Mercury has the weakest weather of all the planets. The atmosphere of the solar system's innermost world is more akin to a vacuum than Earth's protective blanket. This makes for a daily forecast of perennial black skies surrounding a fixed Sun that appears twice as large as it does from Earth. With an almost 59-day rotation barely outpacing its 88-day orbit, and with virtually no air to exchange solar heat via churning wind cells, one side of the planet fries throughout the mercurian day at 800 degrees Fahrenheit (426 degrees Celsius) while the other is a frigid –290 F (–180 C).

The closest Mercury comes to weather is its one-way version of a water cycle, according to research published in the *Astrophysical Journal Letters* in March 2020. The team showed that intense solar radiation, combined with Mercury's extreme temperature range, may produce some of the planet's permanently shadowed polar ice, which is far more plentiful than that found on the Moon. Scientists have long wondered why such a large difference exists between the two worlds when the cometary contributions to both should have been similar. The likely answer: Mercury's proximity to the Sun.

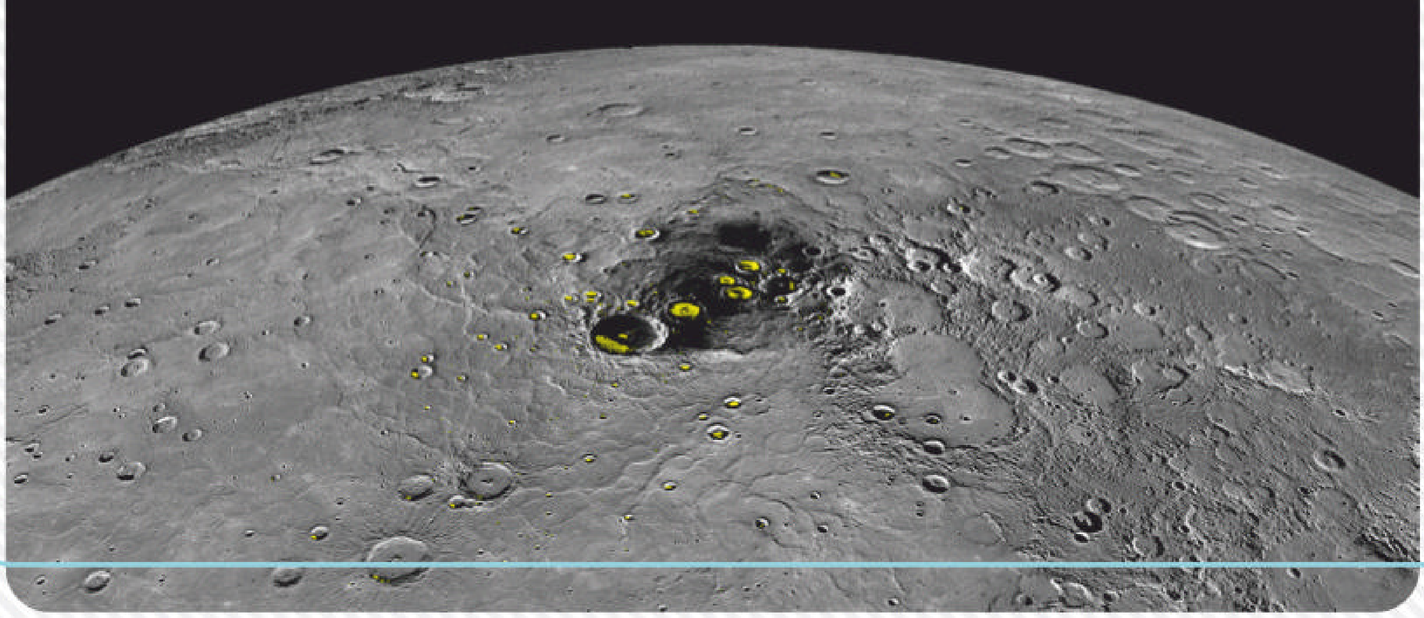
The researchers showed that some of the glacial ice sequestered in Mercury's polar craters — detected by NASA's MESSENGER spacecraft — could come from the constant storm of solar protons raining

NASA's MESSENGER spacecraft transmitted this false-color image of Mercury, accentuating the various surface details of the planet. NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/CARNEGIE INSTITUTION OF WASHINGTON

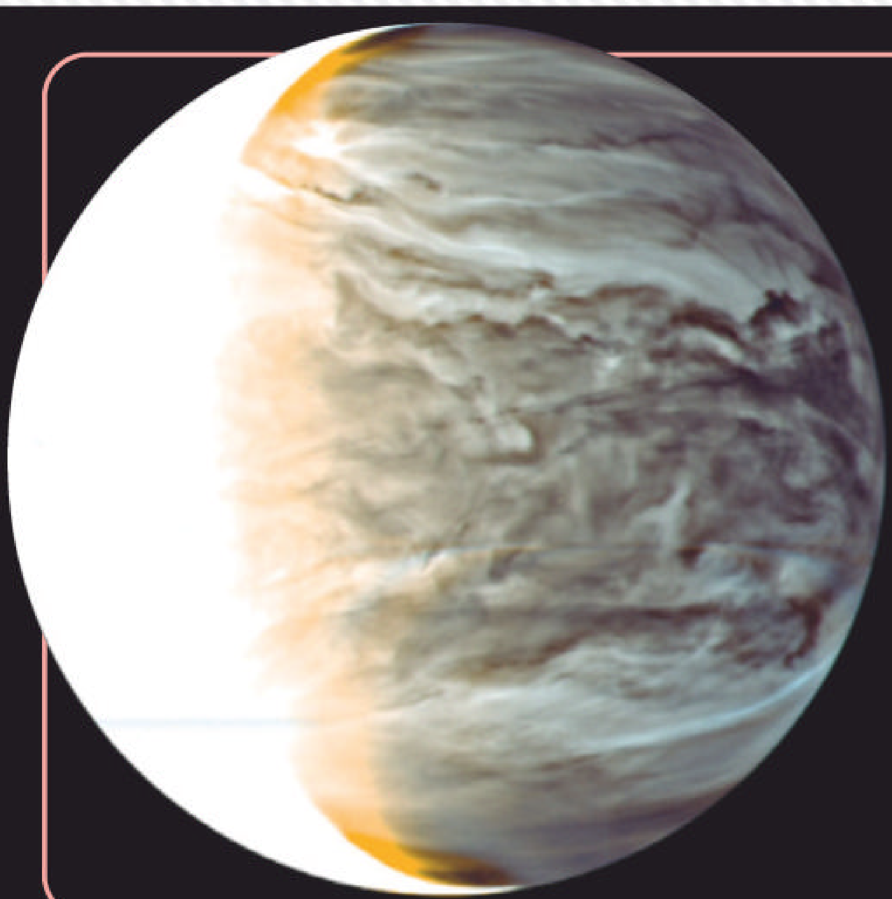
NASA/JPL

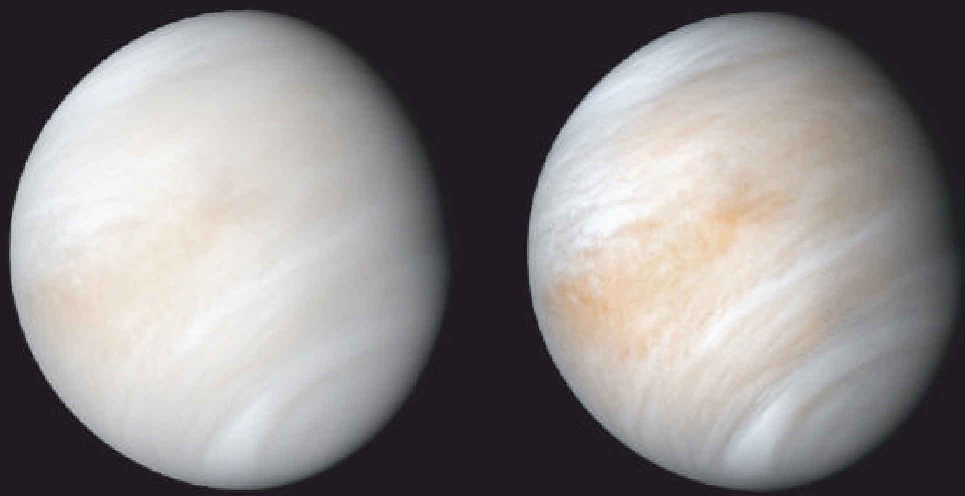
SOLAR SYSTEM

BY RANDALL HYMAN



Water ice resides in the shadows of craters on Mercury. Using data from Arecibo Observatory in Puerto Rico, researchers have identified evidence of such ice (yellow) at the planet's north pole. NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/CARNEGIE INSTITUTION OF WASHINGTON





ABOVE: The clouds in these images, taken by the Mariner 10 spacecraft, lie some 40 miles (60 km) above Venus' surface and are comprised of sulfuric acid particles. NASA/JPL-CALTECH

LEFT: When the Japan Aerospace Exploration Agency's Akatsuki spacecraft finally reached Venus in 2016, it captured this infrared image. The left side of our sister planet is bathed in sunlight while the night side (right) shows the intricacies of Venus' atmosphere. ISAS, JAXA

upon its surface. Water molecules could spring from these protons reacting with hydroxyl minerals in the mercurian soil, producing H_2O. The same process can be triggered by small meteors smashing into the planet, unleashing their own storm of loose protons.

A small percentage of that H_2O could become trapped as ice in polar craters over millions of years. "It's a little like the song 'Hotel California.' The water molecules can check in to the shadows, but they can never leave," said principal investigator Thomas Orlando in a press release.

With little else on the radar, Mercury's long days will remain remarkably predictable for years to come.

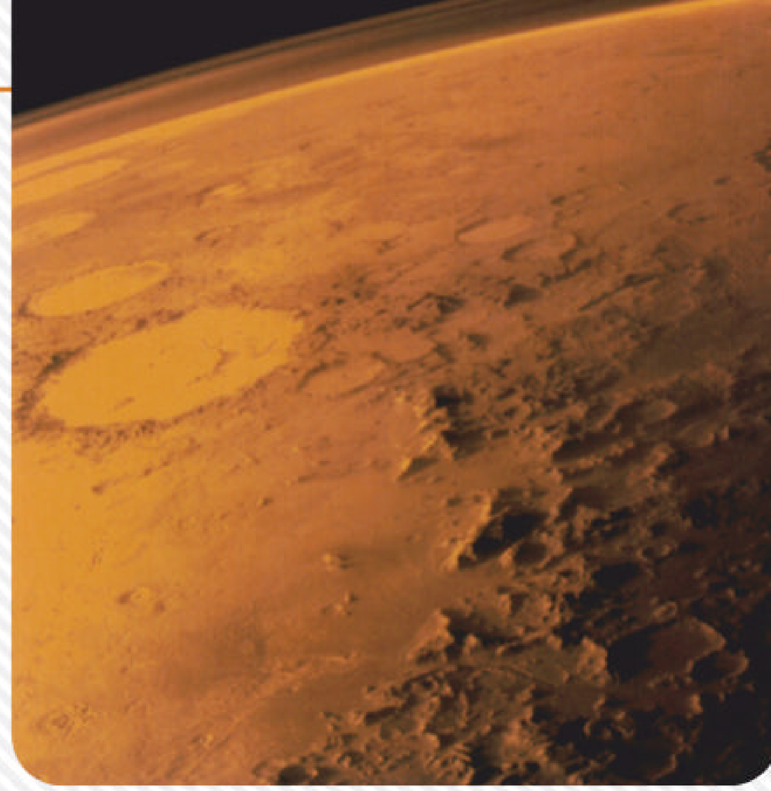
Venus, too, boasts a stable forecast, but hardly a boring one. The planet's atmosphere is mostly carbon dioxide (CO_2), causing nightmarish global warming. The abundant CO_2 traps most incoming solar radiation, producing surface temperatures around 900 F (480 C). If humans were ever to visit — and could somehow manage to withstand the planet's crushing atmospheric pressure — they would be summarily speed-broiled. Thus, at just under two hours, a hardened Soviet Venera lander from 1978 holds the surface survival record.

Venus is famous for being the hottest planet in the solar system, as well as the closest in size and mass to Earth. But our sister world is also the only rocky planet that rotates backward.

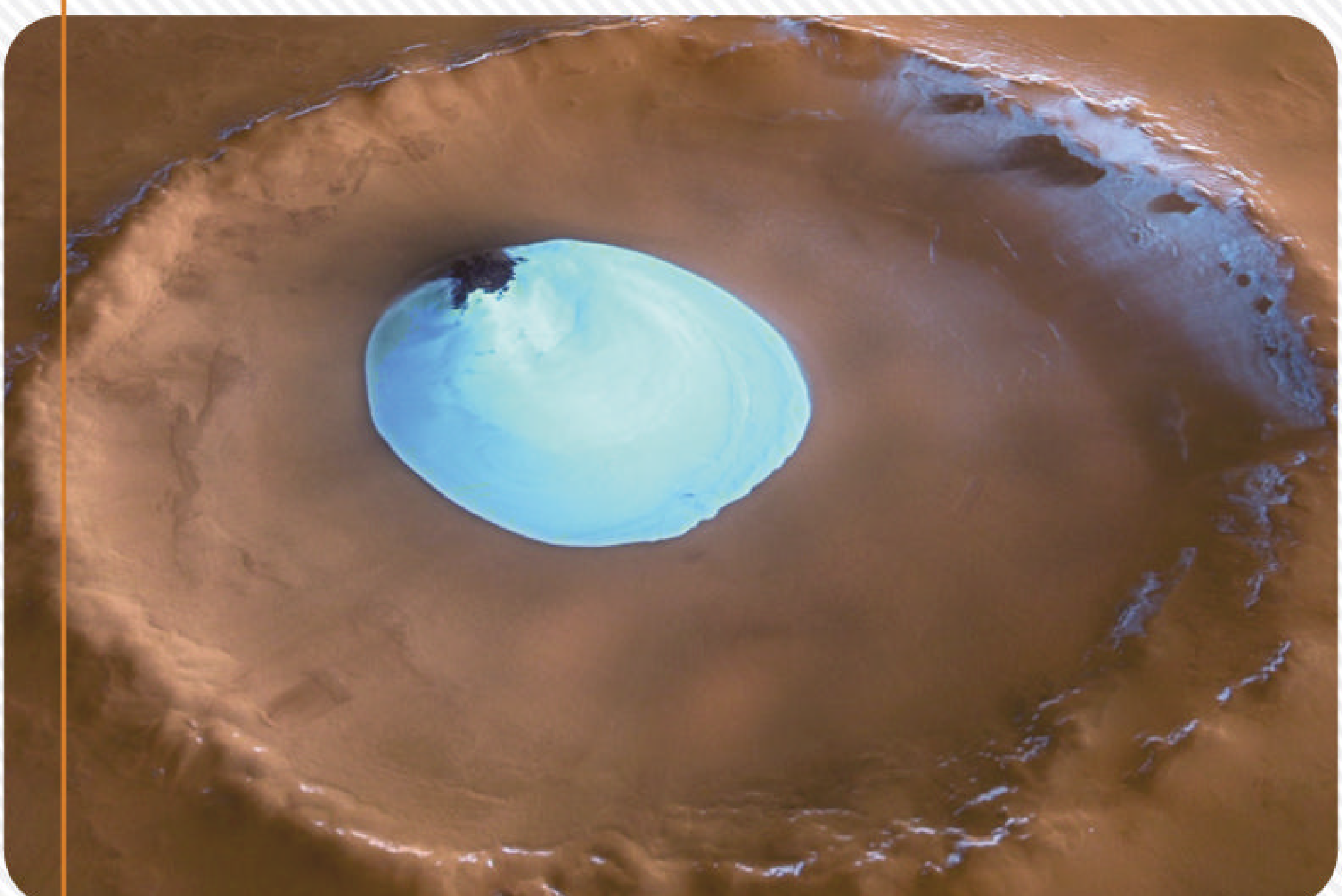
Like Mercury, Venus bakes mostly on one side, since a day on the scorching world is some 18 days longer than its year — though Venus does manage to fit two sunrises into its 225-day trek around our star. The additional ingredient of a thick atmosphere results in violent heat exchange and tornado-force winds in the middle and upper levels. While evenly distributed greenhouse heating keeps winds calm at the surface, the imbalance of solar radiation at higher levels whips the venusian atmosphere around the entire planet in just four days. A decade ago, Europe's Venus Express orbiter recorded a 33 percent jump in wind speed from 186 mph (300 km/h) to 248 mph (400 km/h).

With recent contested claims of a microbial biosignature called phosphine in Venus' high sulfuric clouds, interest in our nearest neighbor has skyrocketed. A trio of NASA and ESA missions, planned to launch around the early 2030s, will study Venus' terrain and geological evolution, and determine whether life is hiding in the planet's upper atmosphere.

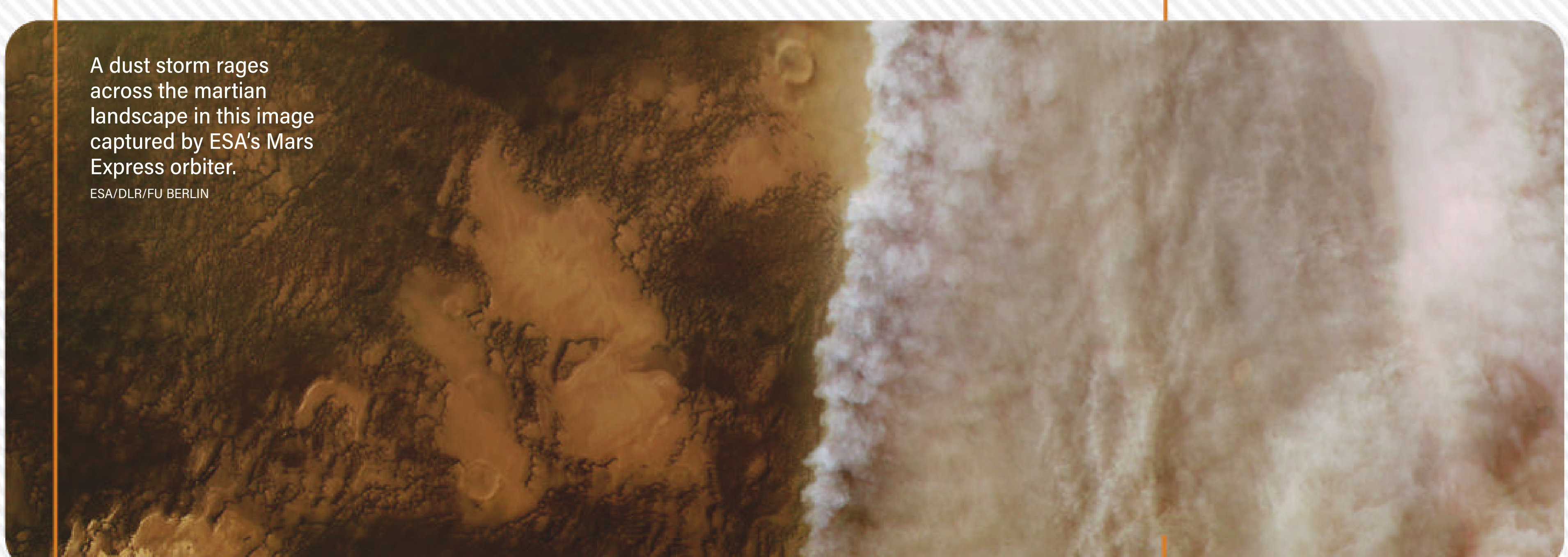
Clouds drift across the martian sky in this image captured by NASA's Opportunity rover's Pancam. NASA/JPL-CALTECH/CORNELL



Mars' atmosphere is approximately 95 percent (by volume) carbon dioxide, 2.6 percent molecular nitrogen, 1.9 percent argon, 0.16 percent molecular oxygen, and 0.06 percent carbon monoxide. NASA/GODDARD SPACE FLIGHT CENTER



Like Earth, Mars has ice at its north pole. Because this particular patch is present all year round, it cannot be carbon dioxide ice and is instead likely water ice. ESA/DLR/FU BERLIN (G. NEUKUM)



A dust storm rages across the martian landscape in this image captured by ESA's Mars Express orbiter. ESA/DLR/FU BERLIN

MORE UPCOMING INTREPID EXPLORERS

MERCURY

BepiColombo — a joint mission between the European Space Agency (ESA) and the Japan Aerospace Exploration Agency — launched in 2018 and will enter orbit around the solar system's innermost planet in 2025. There, it will study Mercury's composition, geophysics, atmosphere, magnetosphere, and history.

VENUS

NASA's DAVINCI (short for Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging) will measure the composition of Venus' atmosphere at every level as the probe descends from the cloud tops to the ground. It is anticipated to launch later this decade. And EnVision, a joint mission from ESA and NASA, will provide a holistic view of Venus, from its inner core to upper atmosphere, when it launches in the early 2030s.

JUPITER

ESA's JUICE (JUpiter ICy moons Explorer) has a planned launch for 2022 and will study three of the gas giant's moons — Europa, Ganymede, and Callisto — which researchers believe harbor subsurface oceans. While in the system, the craft will also peer at the jovian atmosphere and magnetosphere.

Like Venus, Mars' skies are mostly filled with CO_2. But like Mercury, its atmosphere is extremely thin — a mere 1 percent as dense as Earth's.

The diminished martian atmosphere still produces winds strong enough (about 60 mph [97 km/h]) to create dust storms that can be seen from Earth. About once a year, the Red Planet experiences a continent-sized dust storm that can lasts for a few weeks. And about once every three Mars years, a global dust storm kicks up.

That isn't the only seasonal weather that Mars sees. At either pole sits an ice cap — Planum Boreum (north) and Planum Australe (south). These caps are layered, like a stack of pancakes. On the bottom, sand and dust are glued together with water ice. On top of that sits layers of water ice mixed with dust that fell out of the atmosphere over thousands of years. These layers make up the bulk of the ice caps. Just below the top layer sits mostly pure water ice. The topmost layer is composed of CO_2 ice that waxes and wanes over the course of the martian year.

In the winter, when temperatures are around -243 F (-153 C), Mars becomes cold enough for CO_2 in the atmosphere to freeze. About 25 percent of the martian atmosphere condenses in these seasonal ice caps. As the planet warms in the summer, the CO_2 returns to a gas.

THE GAS GIANTS

Beyond Mars, solar system weather gets really spicy. A normal forecast on Jupiter includes freezing temperatures of –160 F (–110 C), lightning, and a chance of mushballs.

Lightning seen on Jupiter isn't too far off from what we experience on Earth, except on Jupiter it stretches above where scientists believe the necessary water clouds exist. Recent observations from the Juno spacecraft may have solved the mystery, however.

Unlike Earth, Jupiter's atmosphere also contains plenty of ammonia, a great antifreeze. Deeper thunderclouds could be a mixture of ammonia and water, creating a secondary weather effect: the aforementioned mushballs.

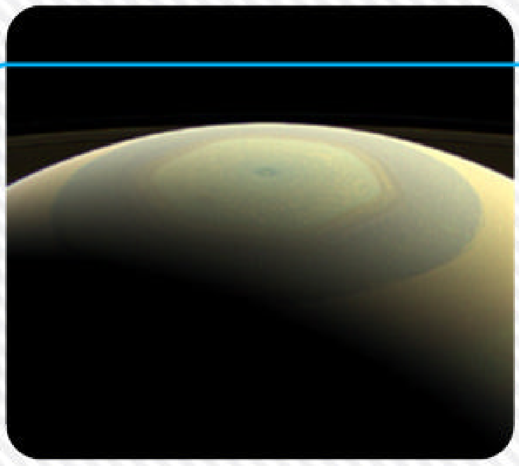
On Earth, hail forms when an airborne drop of water freezes and then gets tossed around, gaining more ice layers. Eventually, the icy ball becomes too heavy for winds to support, and it falls as hail. In Jupiter's cloud tops, the mixed-in ammonia would prevent a water droplet from fully freezing. So water-ammonia slushballs are thrown around, accumulating ice before falling lower in the atmosphere. Scientists also suspect the water trapped in these mushballs makes it possible for Jupiter's upper clouds to have the electrical charge needed for lightning.

Of course, Jupiter is most famous for its brilliant red and white bands of alternating winds, crowned by the Great Red Spot. This immense storm — about as wide as Earth and easily visible in backyard telescopes — has been observed for more than 150 years. In 2000, Jupiter also spawned a smaller storm, Oval BA, aka Red Spot Jr. Both rotate counterclockwise in the southern hemisphere. The storms are turbocharged by Jupiter's 28,273 mph (45,500 km/h) equatorial spin and robust internal heat production.

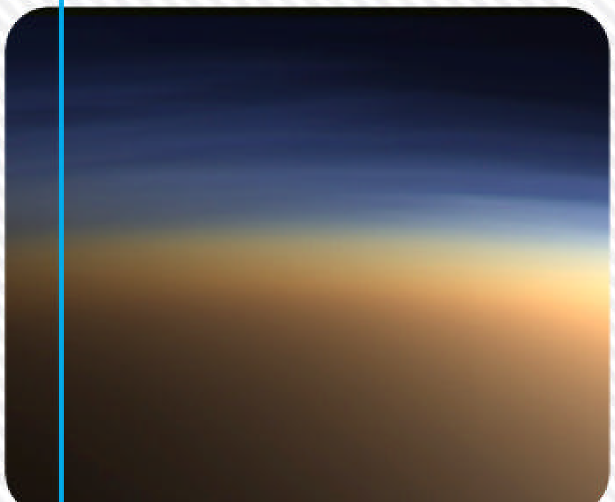
While the Great Red Spot boasts rotational speeds up to 400 mph (644 km/h), astronomers recently discovered stratospheric polar winds moving more than three times as fast beneath the aurorae ringing Jupiter's poles. The team suspects these winds could be part of a giant vortex, which could measure up to four times the size of Earth and reach heights greater than 560 miles (900 km). "A vortex of this size would be a unique meteorological beast in our solar system," said co-author Thibault Cavalié in a press release.

Even more research published this past summer with data from Hawaii's Keck telescope suggests that Jupiter's aurorae — the most intense in the solar system — may be responsible for heating the entire planet. By disrupting the normal poleward flow of heat with massive injections of energy at upper levels, aurorae may heat equatorial regions more than models predict. This anomaly is a decades-long mystery scientists refer to as Jupiter's energy crisis, an mysterious surplus of heat begging some unknown source that could not be explained.

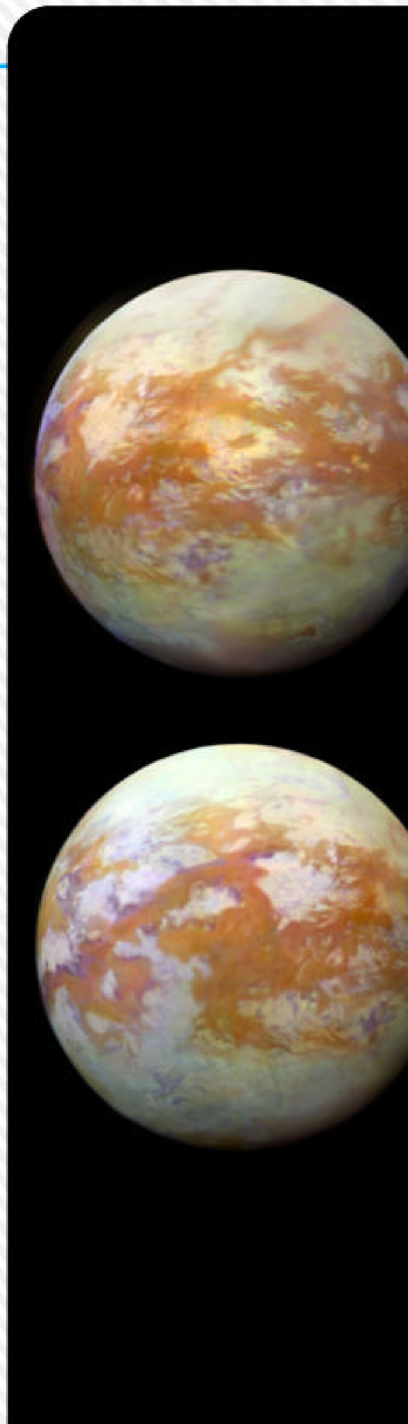
Like Jupiter, Saturn's atmosphere is rich in hydrogen and rife with ammonia-ice clouds. At a frigid –218 F (–138 C), it has jet streams circling its poles. In 2012, NASA's Cassini spacecraft produced vivid photographs of a strikingly geometric jet stream — first detected in the 1980s by the Voyager probes — shooting around the planet's north pole. Scientists aren't quite sure what causes the planet's jet streams to create this unique six-sided shape.



A massive hexagon-shaped hurricane — containing an eye a staggering 1,250 miles (2,000 km) across — lurks at Saturn's north pole. NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

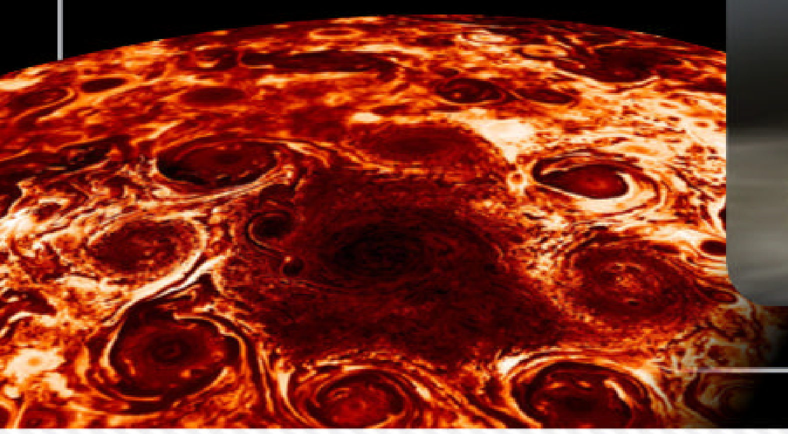


Titan's thick atmosphere acts like a smog, blanketing the surface of the moon from view. NASA/JPL/SPACE SCIENCE INSTITUTE

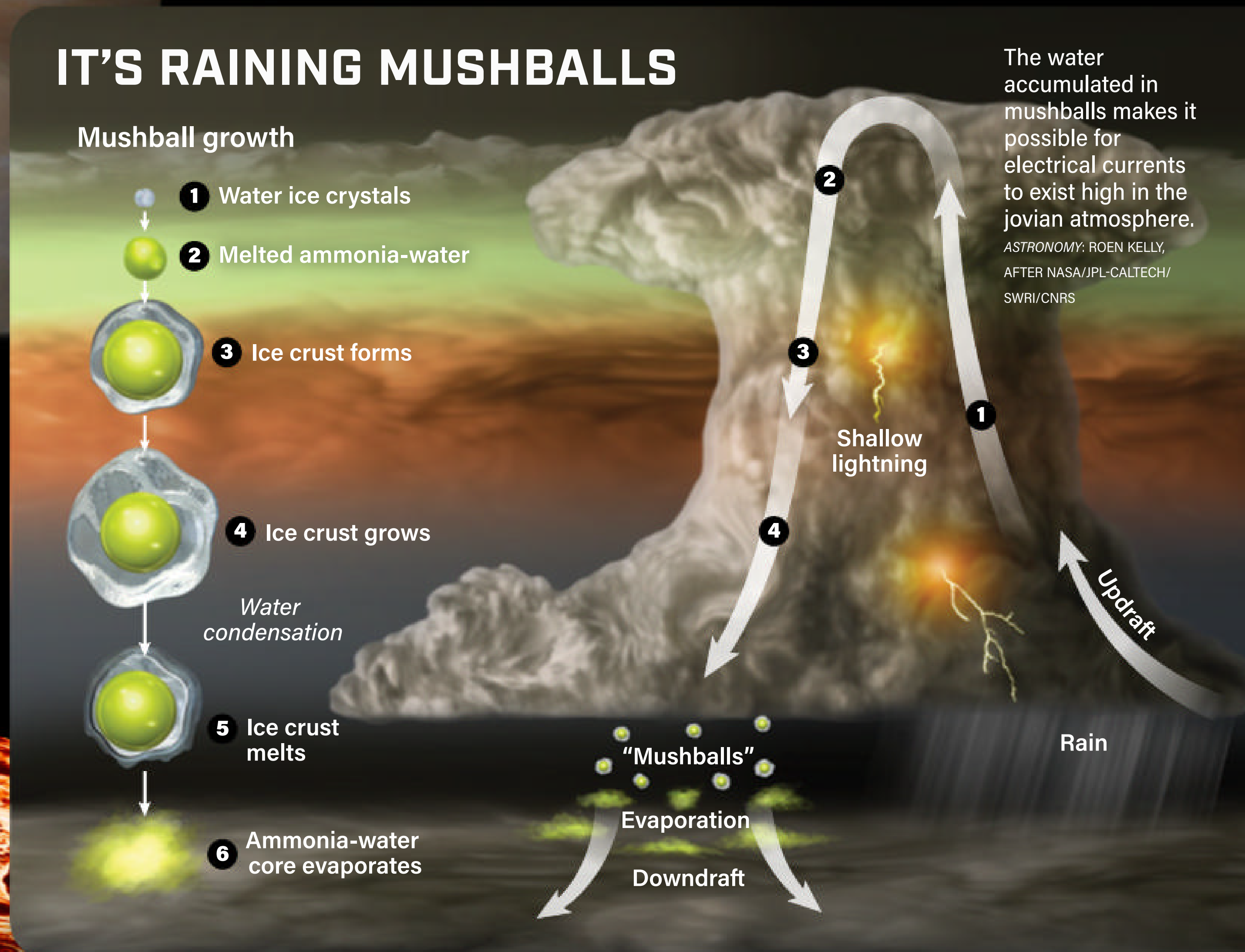


With winds of up to 400 mph (644 km/h), Jupiter's Great Red Spot plows through the clouds ahead of it, creating cascading ribbons in its wake. NASA/JPL/SPACE SCIENCE INSTITUTE

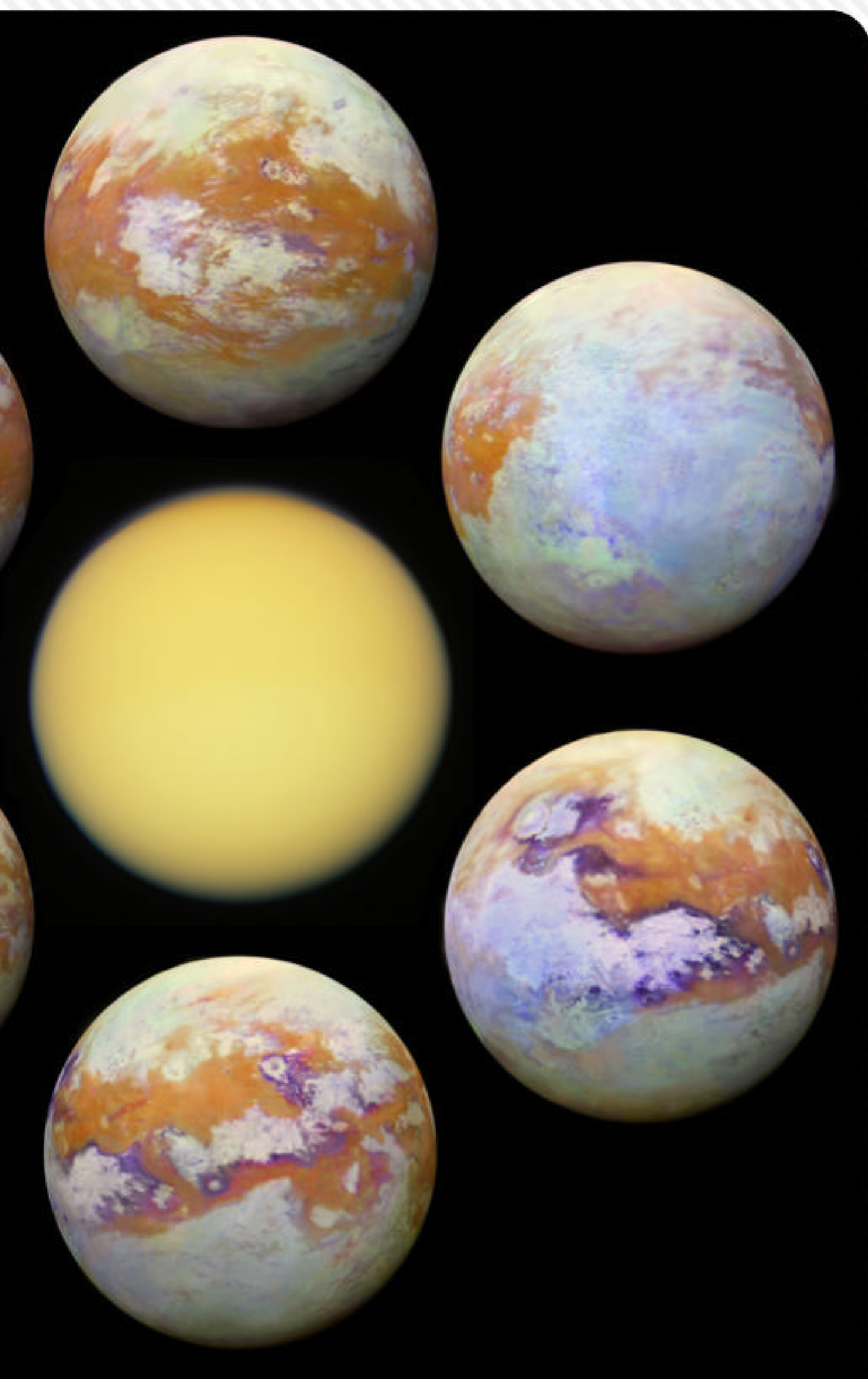
Jupiter's north pole is home to a group of eight cyclones surrounding a central, persistent one, as seen in this image from NASA's Juno mission. NASA/JPL-CALTECH/SWRI/ASI/INAF/JIRAM

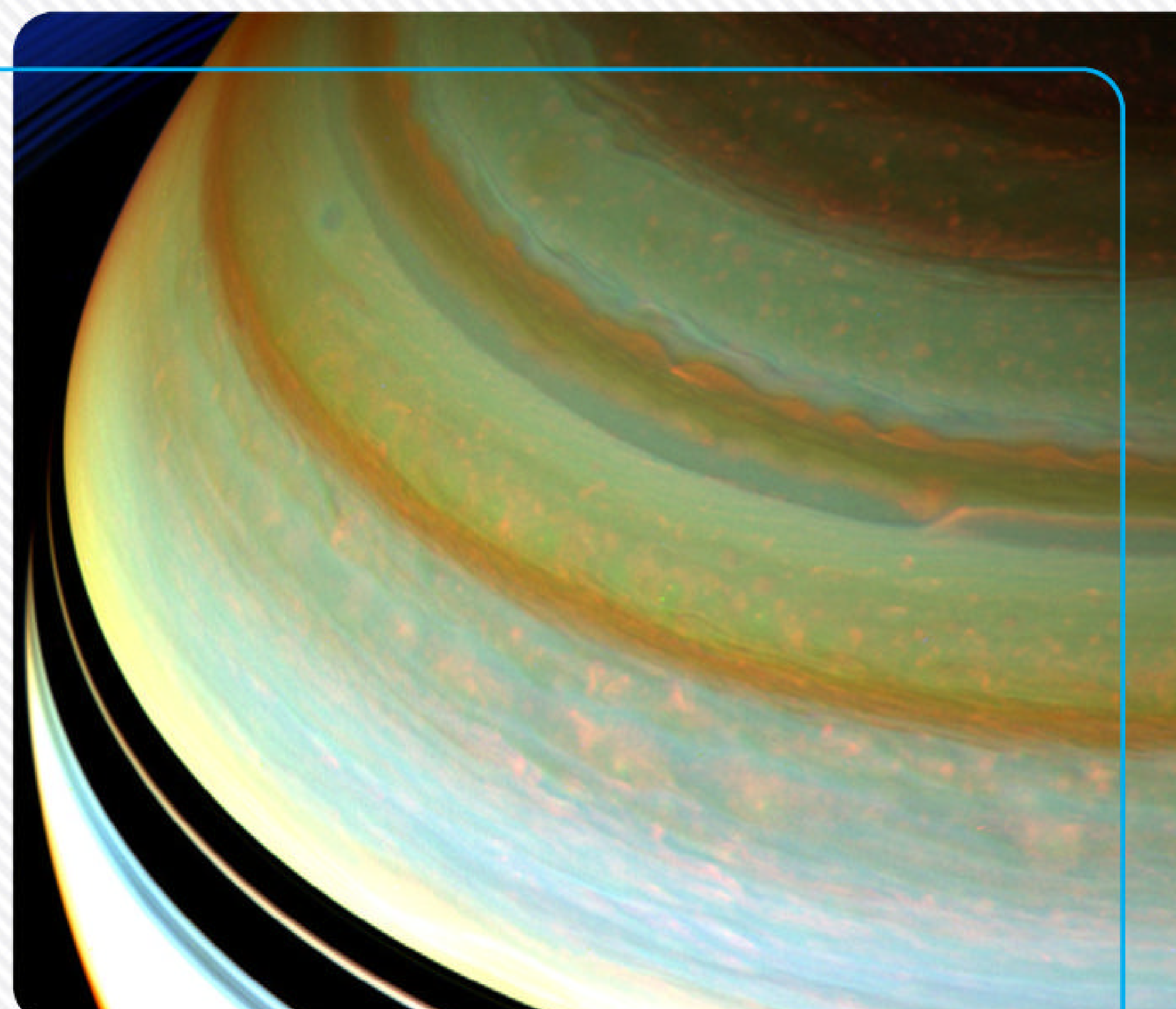


IT'S RAINING MUSHBALLS



The water accumulated in mushballs makes it possible for electrical currents to exist high in the jovian atmosphere. *ASTRONOMY*: ROEN KELLY, AFTER NASA/JPL-CALTECH/SWRI/CNRS

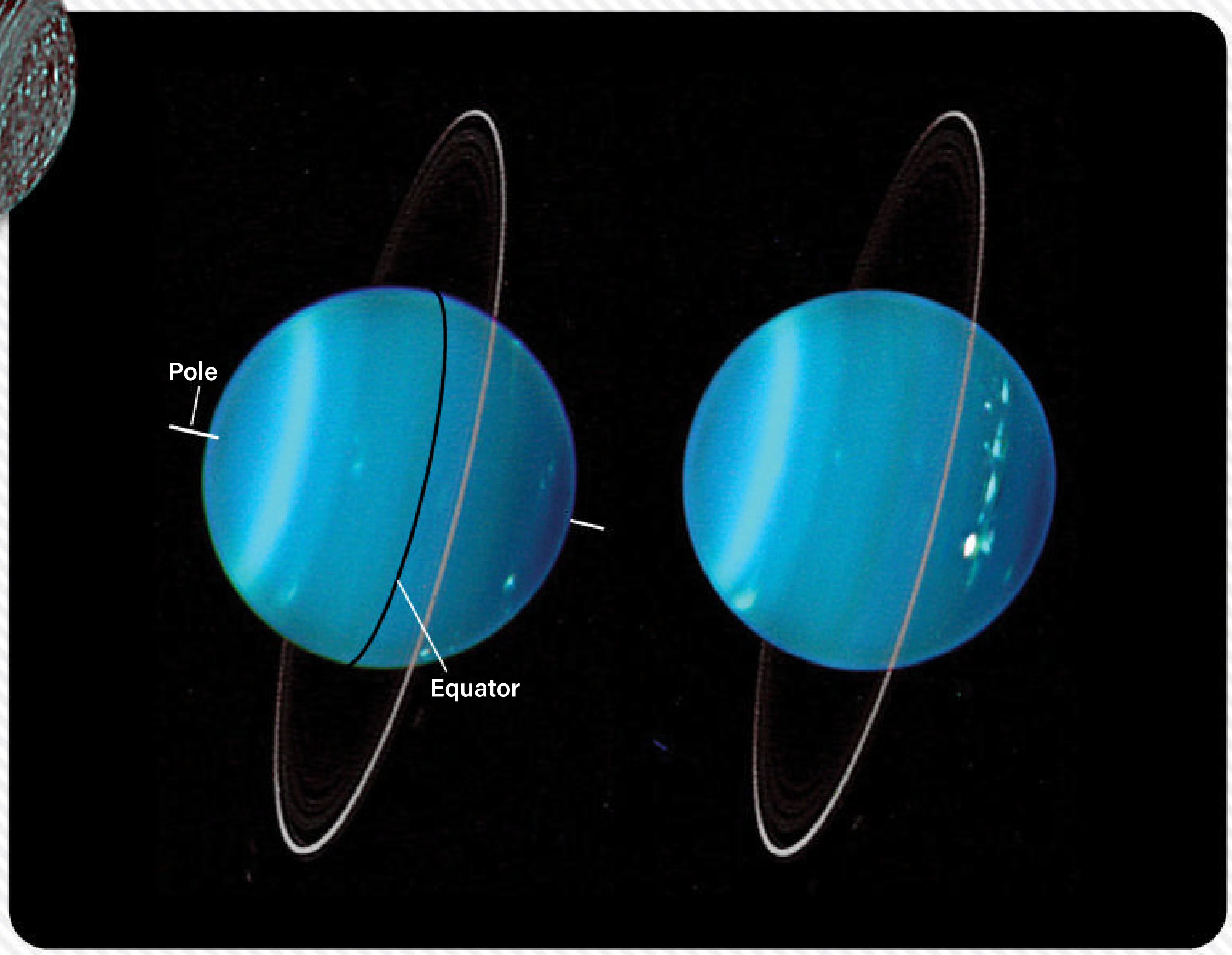




ABOVE: A strong jet stream plows through Saturn's northern hemisphere in this false-color view from NASA's Cassini spacecraft. NASA/JPL-CALTECH/SSI

LEFT: Titan's visible light appearance is shown here (center) compared to six infrared images of the icy moon's surface. NASA/JPL-CALTECH/STÉPHANE LE MOUÉLIC, UNIVERSITY OF NANTES, VIRGINIA PASEK, UNIVERSITY OF ARIZONA; NASA/JPL/SPACE SCIENCE INSTITUTE

ABOVE: Taken using the Keck II telescope in Hawaii, these are the sharpest image scientists have of Uranus' clouds. The planet's north pole (right) is swarmed by stormlike clouds. LAWRENCE SROMOVSKY, PAT FRY, HEIDI HAMMEL, IMKE DE PATER/UNIVERSITY OF WISCONSIN-MADISON



RIGHT: Uranus actually rotates on its side, as seen in this diagram. LAWRENCE SROMOVSKY, UNIVERSITY OF WISCONSIN-MADISON/W.W. KECK OBSERVATORY

Known as the Hexagon, this massive hurricane-like storm above Saturn's north pole has an eye 50 times larger than the eye of the average Earth hurricane.

Saturn also features an exceptionally symmetrical magnetic field. By modeling data taken from Cassini's final orbits and its final plunge into Saturn's atmosphere, researchers revealed this symmetry is most likely maintained by a thick layer of perennial helium rainstorms ringing the poles at high latitudes.

The mission also produced intriguing imagery of Saturn's largest moon, Titan, which is of particular interest to astrobiologists. Titan is the only moon in the solar system with clouds and a dense, nitrogen-rich atmosphere, which is some four times heavier than our own. It is also the only world besides Earth that features liquid on the surface, despite temps hovering near –290 F (–179 C).

During its 13-year mission, Cassini made several flybys of Titan, discovering a subterranean saltwater ocean, lakes and seas of liquid methane near the poles, and vast stretches of arid dunes ringing the equator. When the spacecraft launched the Huygens probe to land on Titan's surface in 2005, photos revealed a fantastical landscape of misty haze, river channels, and dunes.

With an axial tilt of about 27°, Titan has four seasons, each lasting about seven Earth years, and methane rainstorms are thought to flood polar rivers during Titan's summer. NASA plans to send an eight-rotor helicopter, named Dragonfly, to Titan's equator in 2034 in search of life. The dense atmosphere (as compared to the ultrathin air Ingenuity deals with on Mars), should enable it to fly northward in a series of hops covering a total distance more than 108 miles (175 km). Based on seasonal observations from Cassini, NASA forecasters predict calm weather during Dragonfly's tenure.

"We think of Titan as a real-life laboratory where we can see similar chemistry to that of ancient Earth when life was taking hold here," says astrobiologist Melissa Trainer, Dragonfly's deputy principal investigator.

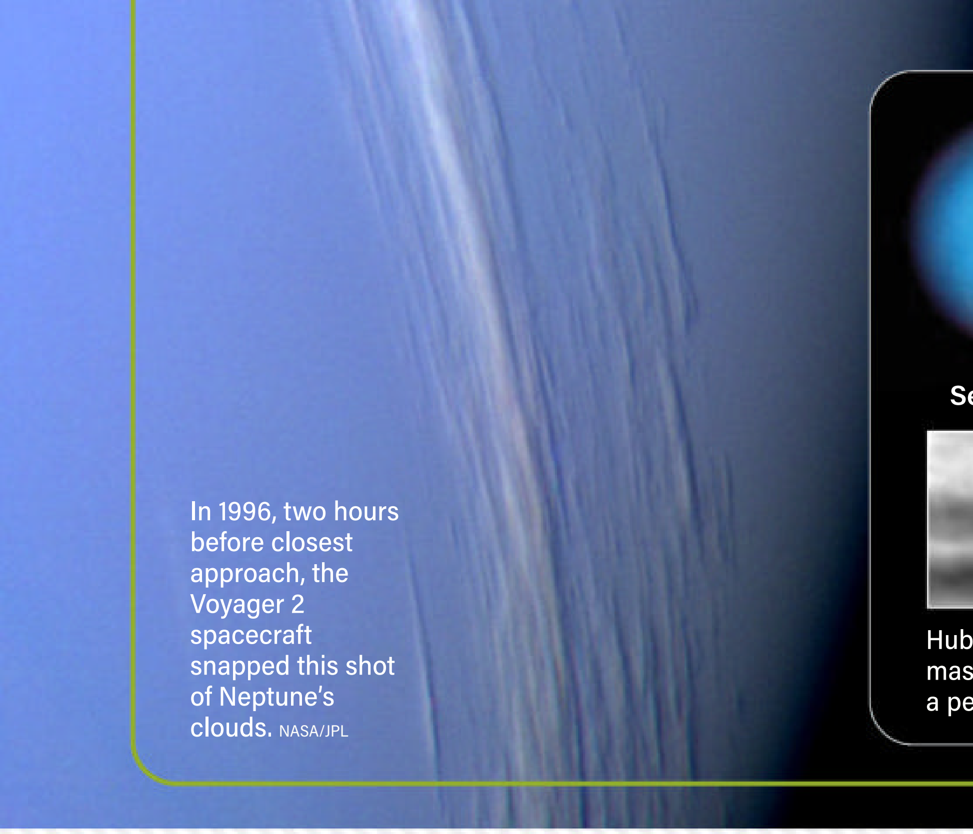
THE ICE GIANTS

Compared to the other planets of the solar system, Uranus and Neptune remain somewhat neglected, with only one probe (Voyager 2) having flown past them. Not much is known about weather on these last two planets, except what can be deduced from Hubble photos and laboratory simulations.

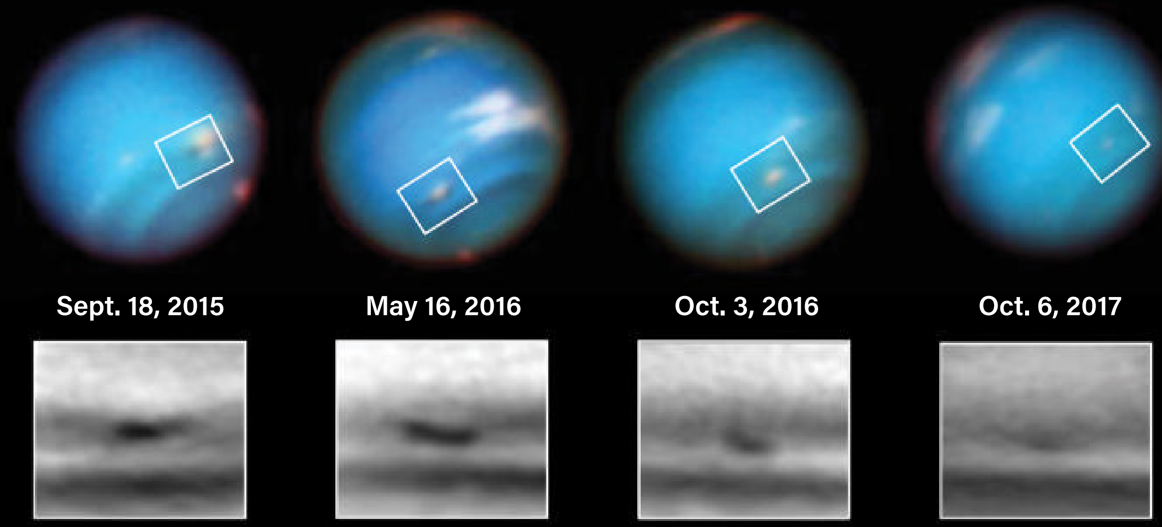
Uranus is the only sideways planet in the solar system, tilted a full 98° to its orbital plane. The extreme tilt places the Sun directly over one pole at a time. The planet's north pole features a prominent cloud cap. Summers and winters last decades and violent storms stalk its hydrogen-rich atmosphere during the seasonal transitions. Hubble images have revealed other clouds circling the planet at over 300 mph (483 km/h).

Neptune, on the other hand, features vast, white, methane-ice cirrus clouds and mysterious dark storms dubbed dark spots. Like all four giant planets, it has an atmosphere of mostly hydrogen with some helium and a pinch of methane. Unlike Jupiter's prominent storms, the internal dynamics of its cyclones are unknown.

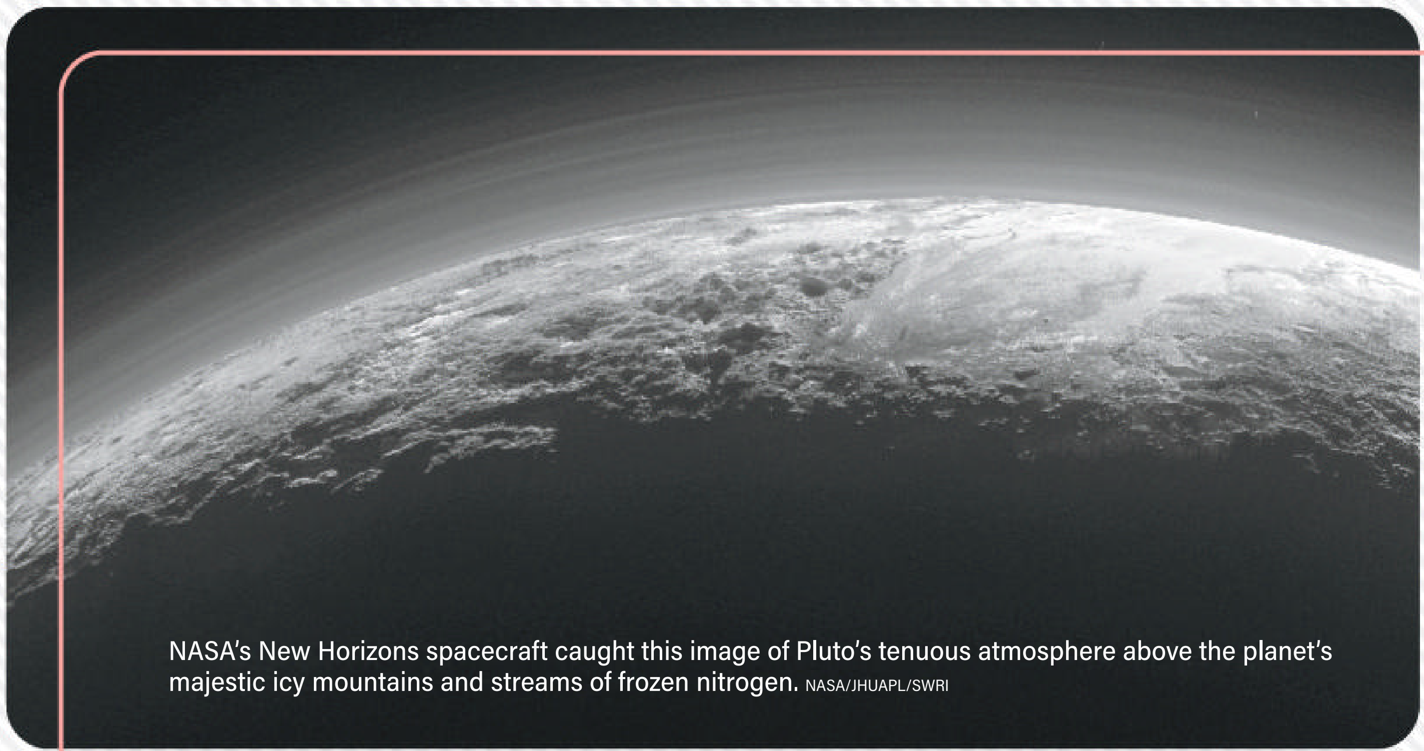
Another mystery is the relative dearth of ammonia on the ice giants, both of which



In 1996, two hours before closest approach, the Voyager 2 spacecraft snapped this shot of Neptune's clouds. NASA/JPL



Hubble spotted a storm swirling around Neptune's atmosphere in 2015. Surprisingly, the massive storm shrunk from about 3,100 miles (5,000 km) to 2,300 miles (3,700 km) wide over a period of two years. NASA, ESA, AND M.H. WONG AND A.I. HSU (UC BERKELEY)



NASA's New Horizons spacecraft caught this image of Pluto's tenuous atmosphere above the planet's majestic icy mountains and streams of frozen nitrogen. NASA/JHUAPL/SWRI

Pluto's famous heart isn't just a nitrogen glacier. Every day, some of the ice in Sputnik Planitia vaporizes only to refreeze when the temperature plunge again at night. NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE/ALEX PARKER

seemingly should have high-altitude abundances similar to Jupiter and Saturn. According to scientists at the 2021 meeting of the Europlanet Science Congress, Jupiter-like mushball storms on Uranus and Neptune could be shunting ammonia away from upper cloud layers — where it is easily detectable — to deep within the atmosphere, where its presence is cloaked from present technology.

And, if another theory, hatched in 1981, is right, Neptune may also host other bizarre storms, including the wildest weather in the solar system: diamond rain. Beneath Neptune's thick hydrogen-helium atmosphere, researchers think, drifts a zone of methane ice. Thanks to the planet's own internal heat and an atmospheric pressure 1 million times that of Earth's, scientists say that these extreme conditions can separate carbon atoms from hydrocarbons and squeeze them into diamonds that fall toward Neptune's core.

THE DWARF PLANET

No tour of our solar system's weather would be complete without a parting visit to our largest dwarf planet, Pluto. It has an even more dramatic tilt than Uranus — 123° — making for ultra-long seasons during its 248-year-long orbit. When NASA's New Horizons spacecraft made its historic flyby in July 2015, it discovered a nitrogen glacier later dubbed Sputnik Planitia.

As New Horizon glanced back at Pluto while barreling off toward interstellar space, it captured glorious views of the backlit body, catching a distinct blue haze rimming the world. Researchers had known Pluto held a thin atmosphere since 1988. A thousand times thinner than the CO_2 atmosphere of Mars, Pluto's nitrogen atmosphere has a heartbeat. Every day, nitrogen ice in Sputnik Planitia vaporizes when sunlight strikes the region. Then, at night, when the temperature plummets, the nitrogen condenses back to ice. This cycle drives 20 mph (32 km/h) winds around Pluto.

As NASA and other space agencies prepare a new fleet of interplanetary spacecraft, weather permitting, we are in for a wild ride through the solar system.

Randall Hyman *is a science writer whose passions have led him from the Arctic to the cosmos for four decades, covering stories for magazines worldwide.*

First look at the 2024 TOTAL

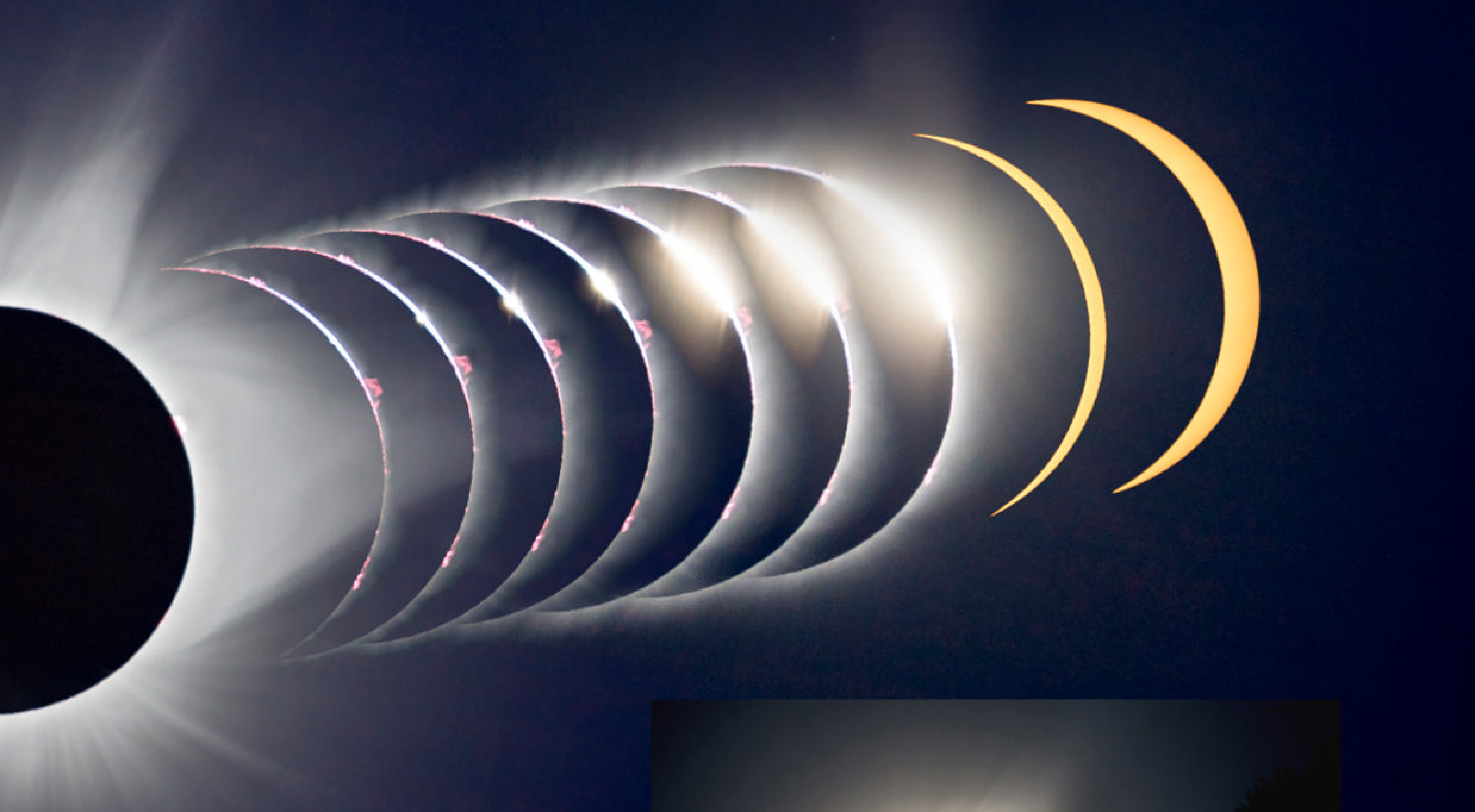
On April 8, 2024, millions of Americans will watch the

LESS THAN FIVE YEARS AGO, IN 2017, millions of people in the U.S. witnessed a spectacular event: the first total solar eclipse to touch the continental U.S. in nearly four decades. The narrow path of American totality started in Oregon and ended in South Carolina, captivating all those fortunate enough to dot its track. But after the excitement of the Great American Eclipse died down, every viewer was left with just one question: "When is the next one?"

The answer, happily, is April 8, 2024. And although six years, seven months, and 19 days sounds like a long time, it's much shorter than the average time between two eclipses appearing at a given location on Earth: every 330 years in the Northern Hemisphere and 550 years south of the equator.

Basics of the eclipse

Because Earth is not always the same distance from the Sun and the Moon is not always the same distance from Earth, the length of totality varies from one total solar eclipse to the next. The Earth-Sun distance changes by about 3 percent and the Moon-Earth distance by as much as 12 percent. Therefore, the maximum duration of totality for



SOLAR ECLIPSE

Moon entirely blot out the Sun. **BY MICHAEL E. BAKICH**

any eclipse occurring between 2000 B.C. and A.D. 3000 is 7 minutes 32 seconds. (Don't get too excited, though — such an extra-long eclipse doesn't occur until July 16, 2186.)

Totality for the 2024 eclipse won't last that long, but it's still a worthy chunk of time: 4 minutes 28 seconds. And as with the Great American Eclipse in 2017, everyone in the contiguous U.S. will at least be treated to a partial eclipse. In fact, the Moon will cover no less than 16.15 percent of the Sun's brilliant surface. (That minimum coverage comes at Tatoosh Island, a tiny speck of land west of Neah Bay, Washington.)

Comparing a partial eclipse to a total eclipse is like comparing almost winning the lottery to winning the lottery.

BACKGROUND: The various stages of the Great American Eclipse of Aug. 21, 2017, are on full display in this composite that captures how the eclipse progressed (from left to right). The placement of each frame roughly matches the actual position and motion of the eclipse across the sky around the time of totality.
ALAN DYER

INSET: Cowboy Nicolas Silva enjoys his view of the total solar eclipse on July 2, 2019, from atop a mountain ridge near Cabalgatas Altos de Cochiguaz, a ranch in Chile's Elqui Valley.
RICK ARMSTRONG

Even partial eclipses can be fun and exciting to watch, especially with a group. This shot, taken during a public event in Centennial Park in Jasper, Alberta, shows the partial eclipse of Oct. 23, 2014, through a handheld solar filter. ALAN DYER

Dense clouds can certainly ruin your eclipse day. But thin wisps of clouds can often make for more dramatic views. This is especially true for partial eclipses, such as this one photographed in October 2014. ALAN DYER

If you are outside during a solar eclipse with 16 percent coverage, eclipse glasses will reveal the Moon taking a small bite out of the Sun's disk, but you won't even notice the sky getting darker with your naked eyes. And it doesn't matter whether the partial eclipse above your location is 16, 56, or 96 percent, you won't see the true celestial spectacles: two diamond rings, the Sun's glorious corona, 360° of sunset, and stars showing themselves in the daytime.

To glimpse any of these, you must be in the path of totality. That said, your next goal is to be as close to the center line as possible. The fact that the Moon's shadow is round means that the longest eclipse occurs at its center line, because that's where the lunar shadow's full width will pass over you.

The big day: April 8, 2024

The Moon's shadow first touches Earth just north of Penrhyn Island, an atoll in the Cook Islands in the South Pacific. That spot will experience a 98 percent partial eclipse. Some 73 minutes later, totality first strikes land at Socorro Island, a possession of Mexico. If you choose to view the eclipse from there, be sure to position yourself at the island's far southeastern tip, where you'll enjoy an extra 34 seconds of totality.

The shadow's path covers a few more tiny islands before it encounters North America just southeast of Mazatlán, Mexico. Viewers at that location will enjoy an impressive 4 minutes 27 seconds of totality. And if you wish to stay in Mazatlán itself, you'll lose only about 10 seconds.

The greatest duration of totality — 4 minutes 28.1 seconds — occurs when the Moon's shadow reaches San Martín,

north of Torreón and roughly half the distance from the coast to the Mexican border with Texas. Fortunately, the duration of totality along the center line is never more than one second less than this maximum during the shadow's more than 550-mile (885 kilometers) voyage through Mexico.

Crossing the border

Totality first reaches the U.S. when the Moon's shadow crosses the Rio Grande River at the wonderfully named Radar Base, Texas, which lies in Maverick County. There, totality lasts 4 minutes 27 seconds. As the eclipse progresses through the Lone Star State, a huge number of people won't have to travel anywhere to view it. That said, venturing just a few miles to the center line is surely worth your while.

San Antonio, Austin, Waco, Dallas, and Fort Worth all lie under the shadow, although none is on the center line. That's more than 11 million people who can experience the total eclipse with little to no effort — and we're not even out of Texas yet.

The center line then passes through Oklahoma, Arkansas, Missouri, Illinois, Indiana, Ohio, Pennsylvania, New York, Vermont, and Maine. Those wishing to observe the eclipse from the same location the center line crossed during the Aug. 21, 2017, eclipse should head to a location near Makanda, Illinois, just south of Carbondale. But a word of warning, if I may: The weather in Illinois in April — and I'm specifically talking about cloud cover here — is a far cry from what it is in August. Your chances of actually seeing the 2024 eclipse increase dramatically as you move southwest.

Other major cities in the 2024 eclipse path include Little Rock, Arkansas; Indianapolis, Indiana; Dayton and Cleveland, Ohio (with northwestern parts of Cincinnati and Columbus under the shadow); Buffalo, Rochester, and Syracuse, New York; and about half of Montréal, Québec, Canada.

But if some of these places don't float your boat, don't worry. There are plenty of other great options.

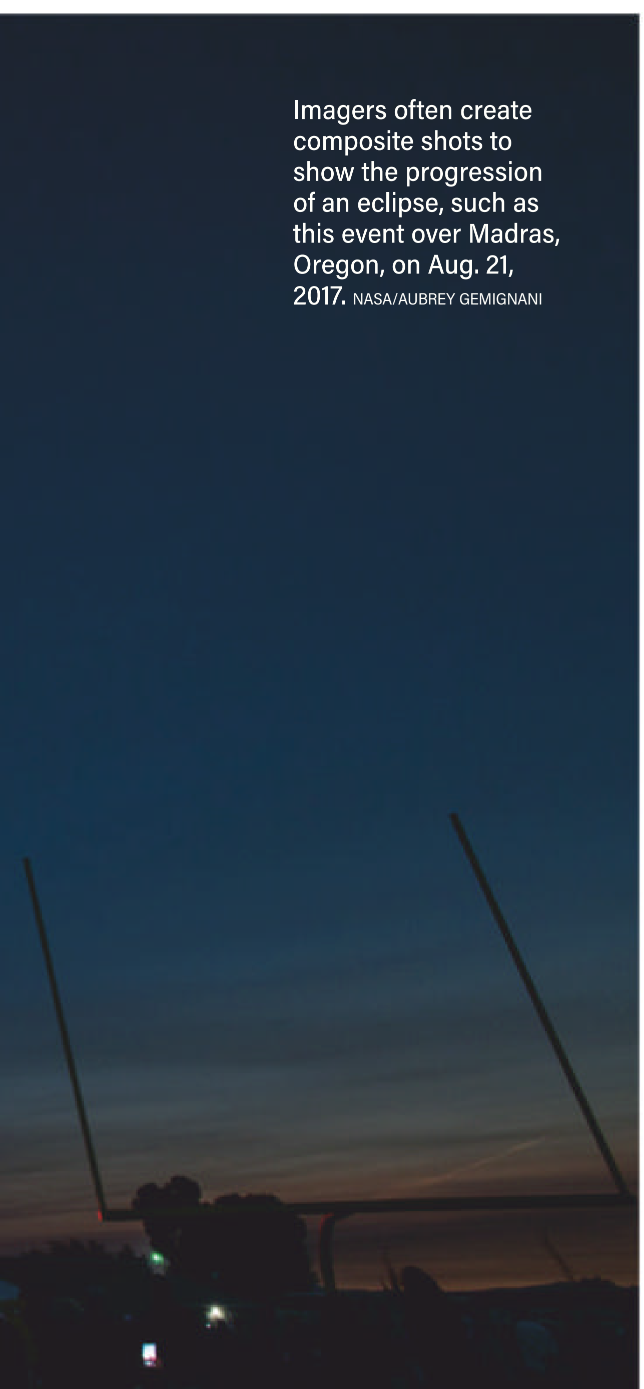
— Continued on page 30

FAST FACTS

A solar eclipse lines up the Sun, the Moon, and Earth. The Moon, directly between the Sun and Earth, casts a shadow on our planet. If you're in the dark part of that shadow (the umbra), you'll see a total eclipse. If you're in the light part (the penumbra), you'll see a partial eclipse.

Tons of people will see it. In 2017, approximately 12.25 million residents of the U.S. lived along the path of totality. In 2024, more than that number live along the path before the eclipse leaves Texas! In all, approximately 31.5 million people across 15 states can simply walk outside, look up, and see a totally eclipsed Sun in the daytime sky — weather permitting, of course.

This event will happen! As astronomers, some of the problems we encounter are due to the uncertainty and limited visibility of celestial events. Comets may appear bright if their compositions are just so. Meteor showers might reach storm levels if we pass through a thick part of the stream. A supernova as bright as a whole galaxy could be visible now, but you need a telescope to view it. In contrast, the 2024 total solar eclipse will occur when we say, where we say, for how long we say, and in the daytime, no less. Guaranteed! *— M.E.B.*



Imagers often create composite shots to show the progression of an eclipse, such as this event over Madras, Oregon, on Aug. 21, 2017. NASA/AUBREY GEMIGNANI

This composite of the total solar eclipse of March 29, 2006, was taken from Libya. It shows the diamond ring formed during second contact at top left, totality at center, and the third-contact diamond ring at bottom right. You might also notice the New Moon's usually invisible face is slightly illuminated by earthshine — sunlight reflecting off our planet and back at the Moon — during totality. ALAN DYER

12 OF THE BEST PLACES TO VIEW THE 2024 TOTAL ECLIPSE

THE TOTAL SOLAR ECLIPSE OF APRIL 8, 2024, will dazzle everyone who views it. And by using maps like the one on the next page, it's easy to find the specific cities in Mexico and the U.S. where totality will grace the skies. But where are the best locations to set up shop? That answer is less straightforward.

You'll surely want to be near the eclipse's center line, where totality lasts the longest. But not every place along the center line makes for an ideal viewing site. So, here are 12 great locations you should really consider for the 2024 total solar eclipse, starting in Mexico and working our way to the Northeastern U.S.

I'll also offer another suggestion when choosing a site: Carefully consider the population. All things being equal, a town of 10,000 is more likely to have event-related problems than a city of 75,000. Small towns with one main road may suffer hours of gridlock. If you opt to travel to such a location, get there early, perhaps even a day or two ahead of the eclipse. (Remember: April 8, 2024, is a Monday, and most people will be free the entire weekend beforehand.)

Finally, if you'd like to preview exactly what the eclipse will look like from any location on the big day, visit www.eclipse2024.org/eclipse-simulator/ for an impressively accurate interactive view.

1 Mazatlán, Sinaloa, Mexico

The Moon's umbra touches the coast of the United Mexican States at 11:07 A.M. Mexican Pacific Daylight Time (MPDT), less than 12 miles (19 km) southeast of Mazatlán, which was one of the main destinations for travelers viewing the July 11, 1991, total solar eclipse. This city previously showed it can host a large influx of travelers, so it's a decent bet that it will be a prime destination again.

Eclipse starts: 9:51:28 A.M. MPDT
Maximum eclipse: 11:09:39 A.M. MPDT
Eclipse ends: 12:32:11 P.M. MPDT
Sun's altitude at maximum eclipse: 69.1°
Duration of totality: 4 minutes 18 seconds
Width of Moon's shadow: 123.7 miles (199.1 km)

2 Radar Base, Texas

For eclipse chasers who want the greatest possible amount of totality without leaving the U.S., consider Radar Base, which lies right on the U.S.–Mexico border. While its name might imply a military base, the settlement is actually a small town of several hundred residents. That number will balloon on eclipse day, so be sure to get there early.

Eclipse starts: 12:10:26 P.M. CDT
Maximum eclipse: 1:29:53 P.M. CDT
Eclipse ends: 2:51:30 P.M. CDT
Sun's altitude at maximum eclipse: 68.5°
Duration of totality: 4 minutes 27 seconds
Width of Moon's shadow: 120.9 miles (195.5 km)

3 Hillsboro, Texas

Although not a huge city, Hillsboro is an easy destination, lying on Interstate 35 where I-35E and I-35W split south of Dallas. It also sits right along the center line of totality, which will help maximize your time under the Moon's umbra.

Eclipse starts: 12:21:23 P.M. CDT
Maximum eclipse: 1:40:53 P.M. CDT
Eclipse ends: 3:01:16 P.M. CDT
Sun's altitude at maximum eclipse: 65.5°
Duration of totality: 4 minutes 23 seconds
Width of Moon's shadow: 119.2 miles (191.8 km)

4 Russellville, Arkansas

With a population near 30,000, Russellville has enough resources to host a moderate influx of visitors for the eclipse. Those eclipse chasers who prefer to observe the event outside the city could head for nearby Mount Nebo, a flat-topped mountain that rises 1,350 feet (410 meters) above the surrounding valley.

Eclipse starts: 12:33:08 P.M. CDT
Maximum eclipse: 1:52:10 P.M. CDT
Eclipse ends: 3:10:46 P.M. CDT
Sun's altitude at maximum eclipse: 61°
Duration of totality: 4 minutes 11 seconds
Width of Moon's shadow: 117.2 miles (188.6 km)

5 Cape Girardeau, Missouri

The largest city in southeastern Missouri that will experience totality is Cape Girardeau, with 80,000 residents. It lies on the bank of the Mississippi River and is easily accessible from Interstate 55. For an additional four seconds of totality, eclipseophiles can head 10 miles (16 km) northwest on Route 72 to Jackson.

Eclipse starts: 12:41:51 P.M. CDT
Maximum eclipse: 2:00:21 P.M. CDT
Eclipse ends: 3:17:26 P.M. CDT
Sun's altitude at maximum eclipse: 57.3°
Duration of totality: 4 minutes 6 seconds
Width of Moon's shadow: 115.5 miles (185.9 km)

6 Indianapolis, Indiana

The umbra will cover a wide swath of Indiana, but most of the attention will focus on the state's capital city. Downtown Indianapolis is a metropolis served by four interstate highways and will surely be one of the most sought-after destinations. It offers plentiful lodging, excellent cuisine, and many attractions for travelers.

Eclipse starts: 1:50:31 P.M. EDT
Maximum eclipse: 3:07:56 P.M. EDT
Eclipse ends: 4:23:10 P.M. EDT
Sun's altitude at maximum eclipse: 53°
Duration of totality: 3 minutes 49 seconds
Width of Moon's shadow: 114 miles (183.4 km)

7 Cleveland, Ohio

With a metro population of more than 2 million, this city will host a multitude of eclipse chasers. Get there a couple of days early and fill the waiting time with visits to some of Cleveland's highlights, including the Cleveland Museum of Art and the Rock & Roll Hall of Fame.

Eclipse starts: 1:59:20 P.M. EDT
Maximum eclipse: 3:15:37 P.M. EDT
Eclipse ends: 4:28:57 P.M. EDT
Sun's altitude at maximum eclipse: 48.6°
Duration of totality: 3 minutes 49 seconds
Width of Moon's shadow: 111.9 miles (180.1 km)

The usually invisible solar corona bursts into view in this shot of the 2017 Great American Eclipse. ALAN DYER

ASTRONOMY: ROEN KELLY, AFTER MICHAEL ZEILER

8 Erie, Pennsylvania

The only large city in the Commonwealth of Pennsylvania to be graced by the Moon's umbra is Erie, which, with its 100,000 residents, sits on the shore of the Great Lake that bears its name. It's certain that many eclipse chasers from Pittsburgh, 130 miles (210 km) to the south via Interstate 79, will visit for the event.

Eclipse starts: 2:02:23 P.M. EDT
Maximum eclipse: 3:18:12 P.M. EDT
Eclipse ends: 4:30:48 P.M. EDT
Sun's altitude at maximum eclipse: 47°
Duration of totality: 3 minutes 42 seconds
Width of Moon's shadow: 111.2 miles (179 km)

9 Niagara Falls, New York

If the Northeastern U.S. has good weather on eclipse day, the most picturesque images of the event might come from Niagara Falls. One of the best perspectives will be the outlook called Terrapin Point, where the Sun will hang halfway up in the southwest — directly over the Falls! Science buffs who observe or photograph the eclipse from this area surely will want to visit the Nikola Tesla Monument within Queen Victoria Park on the Canadian side of Niagara Falls. It lies only 0.3 mile (0.5 km) north of Terrapin Point.

Eclipse starts: 2:04:50 P.M. EDT
Maximum eclipse: 3:20:02 P.M. EDT
Eclipse ends: 4:31:57 P.M. EDT
Sun's altitude at maximum eclipse: 45.6°
Duration of totality: 3 minutes 31 seconds
Width of Moon's shadow: 110.8 miles (178.4 km)

10 Buffalo, New York

The largest city in New York to experience the Moon's umbra is Buffalo, with its metropolitan population of 1.1 million. The center line passes right through downtown, so expect all activity to come to a screeching halt in midafternoon. Travelers desiring information about the eclipse might want to check with the staff of Zygmunt Planetarium, which is part of the Buffalo Museum of Science.

Eclipse starts: 2:04:54 P.M. EDT
Maximum eclipse: 3:20:11 P.M. EDT
Eclipse ends: 4:32:07 P.M. EDT
Sun's altitude at maximum eclipse: 45.6°
Duration of totality: 3 minutes 45 seconds
Width of Moon's shadow: 110.7 miles (178.2 km)

11 Sherbrooke, Quebéc, Canada

Those Canadians who may not wish to cross the border can opt for Sherbrooke, which is only a 100-mile (161 km) drive from Montréal. With a metro population of nearly a quarter-million, Sherbrooke offers plenty of lodging and other amenities. A quick 10-mile (16 km) drive south will bring you to the center line and five additional seconds of totality.

Eclipse starts: 2:16:35 P.M. EDT
Maximum eclipse: 3:29:23 P.M. EDT
Eclipse ends: 4:38:13 P.M. EDT
Sun's altitude at maximum eclipse: 38.8°
Duration of totality: 3 minutes 25 seconds
Width of Moon's shadow: 107.8 miles (173.5 km)

12 Mars Hill, Maine

To be honest, Mars Hill is a small town of some 1,500 residents. But just think of it: an amateur astronomer watching the Moon cover the Sun from a place named Mars Hill? Terrific. This location also is one of the last spots in the U.S. to see totality. But if you're one of those more serious types, just venture 20 miles (32 km) south for an additional 10 seconds of totality.

Eclipse starts: 2:22:20 P.M. EDT
Maximum eclipse: 3:33:41 P.M. EDT
Eclipse ends: 4:40:52 P.M. EDT
Sun's altitude at maximum eclipse: 35.2°
Duration of totality: 3 minutes 12 seconds
Width of Moon's shadow: 106.2 miles (171 km)

Drive safely and don't forget your eclipse glasses. I wish you all clear skies! *—M.E.B.*

QUICK TIPS

Request a vacation day. Although it's nearly three years before the great event, April 8, 2024, will surely be a popular vacation day. If 2021 or 2022 are too early to submit your vacation request, set a reminder now to do so in 2023.

Watch the sunset all around. After totality begins, the horizon will take on an eerie glow. On the leading edge of the shadow, sunset is happening. On the following edge, sunrise is occurring. The 360° sunset is one of the coolest earthly sights during any total solar eclipse. But don't dwell on it too long. The real drama is in the sky.

Time will fly. In the "Forum" section of the August 1980 issue of *Astronomy*, columnist Norm Sperling tried to convey how quickly totality speeds by. He wrote: "Everyone who sees a total solar eclipse remembers it forever. It overwhelms the senses, and the soul as well — the curdling doom of the onrushing umbra, the otherworldly pink prominences, and the ethereal pearly corona. And incredibly soon, totality terminates. Then it hits you: 'It was supposed to last a few minutes — but that couldn't have been true. It only seemed to last eight seconds!'"
—M.E.B.

Photographed Aug. 11, 1999, from Hasankayef — a village and archeological site along the Tigris River in southest Turkey — a total solar eclipse dazzles high in the sky above fortress ruins in the foreground. It's hard to imagine what the people who used to live in the homes built into the valleys some 2,000 years ago would have thought if they saw such an unfamiliar sight. ALAN DYER

This spectacular image reveals fine details in the Sun's corona (its outer atmosphere) that you won't be able to spot with your own eyes. IMAGE: DON SABERS AND RON ROYER; PROCESSING: MILOSLAV DRUCKMÜLLER

— Continued from page 27

A long wait after 2024

For those wanting to view another total solar eclipse in the contiguous U.S. after the 2024 event, it'll be a 20-year wait — until Aug. 23, 2044 — for the next one. Plus, that eclipse is visible only in northeastern Montana and a tiny segment of North Dakota. Its greatest duration of totality, 2 minutes 4 seconds, happens over Canada's Northwest Territories.

At the intersection of the center line of the 2044 eclipse and the U.S.-Canada border, totality is 20 seconds shorter: 1 minute 44 seconds. The small towns near that point, namely Hogeland and Turner, Montana, experience totalities only a few tenths of a second less than that. And the Montana cities of Chinook, Zurich, Harlem, Dodson, and Malta lose only another second.

After 2044, three more total solar eclipses track through the contiguous U.S. in the 21st century. So, if 2044's eclipse disappoints you, you'll be thrilled to know that another happens less than one year later. The event, on Aug. 12, 2045, is a truly spectacular cross-country eclipse, with totality lasting from

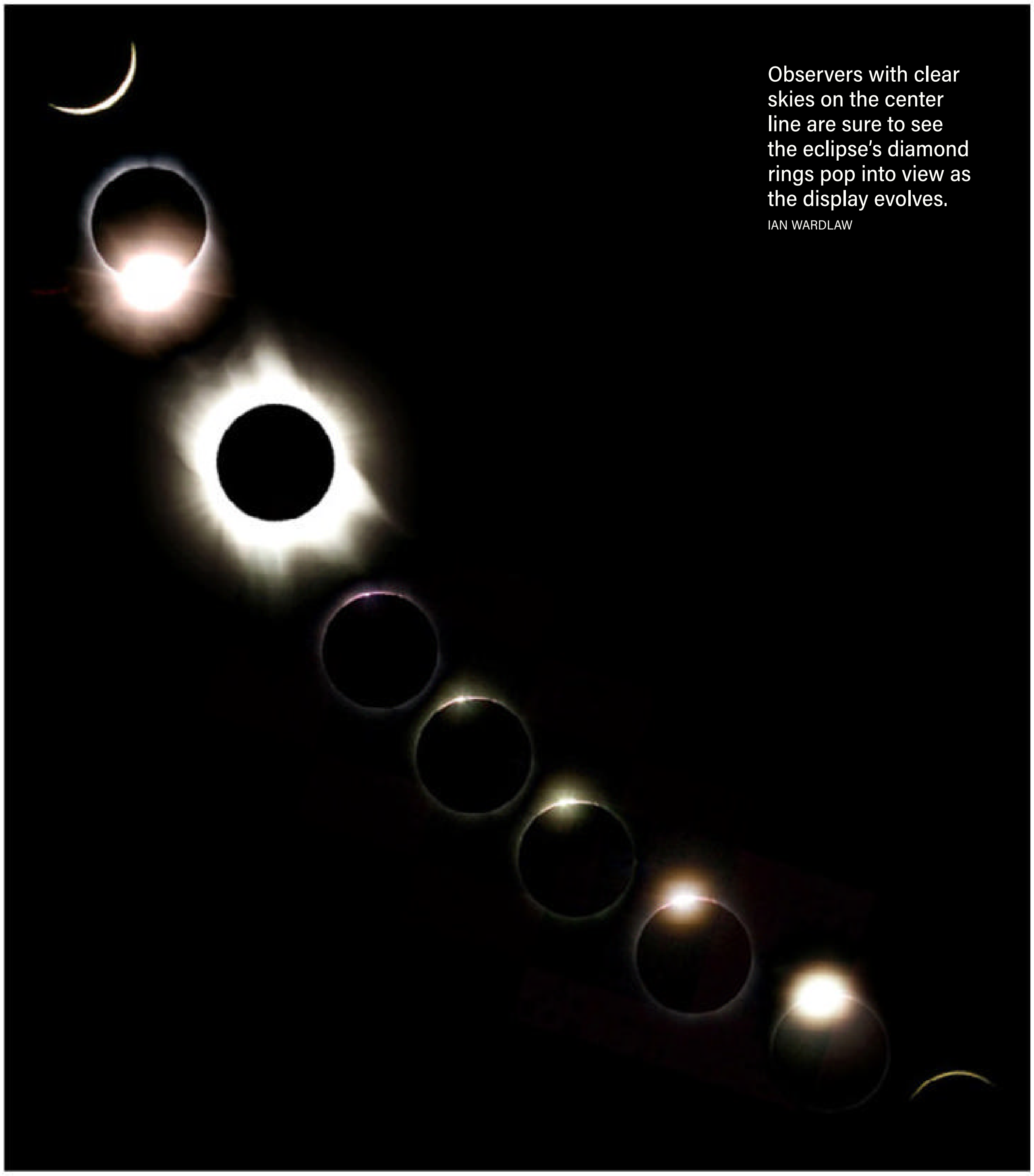
After 2024, another total solar eclipse won't occur in the contiguous U.S. until 2044. But there's no shortage of eclipses around the world before then.
ASTRONOMY: ROEN KELLY, AFTER FRED ESPENAK, NASA/GSFC

4 minutes 23 seconds on the Northern California coast to an amazing maximum of 6 minutes 6 seconds at Port St. Lucie, Florida.

Next, the center line of the total solar eclipse on March 30, 2052, lands only on Florida and Georgia. But totality for that small path will only last between 3 minutes 30 seconds in Savannah, Georgia, and 3 minutes 44 seconds near Laguna Beach, Florida. The final 21st-century total solar eclipse whose path intersects the contiguous U.S. occurs May 11, 2078. Like the eclipse in 2052, this one also tracks through the southeastern U.S. Totality will last 5 minutes 17 seconds in Nags Head, North Carolina.

For those of you who stood beneath the Moon's shadow in 2017, no convincing is needed to get you to seek out darkness in 2024. If you can catch it, an eclipse is a sight you'll never rate as anything other than awesome — in the truest sense of the word. Just be sure to check the weather first!

Michael E. Bakich *is an eclipsophile who has stood beneath the Moon's umbral shadow more than a dozen times.*



Observers with clear skies on the center line are sure to see the eclipse's diamond rings pop into view as the display evolves.
IAN WARDLAW

SKY THIS MONTH

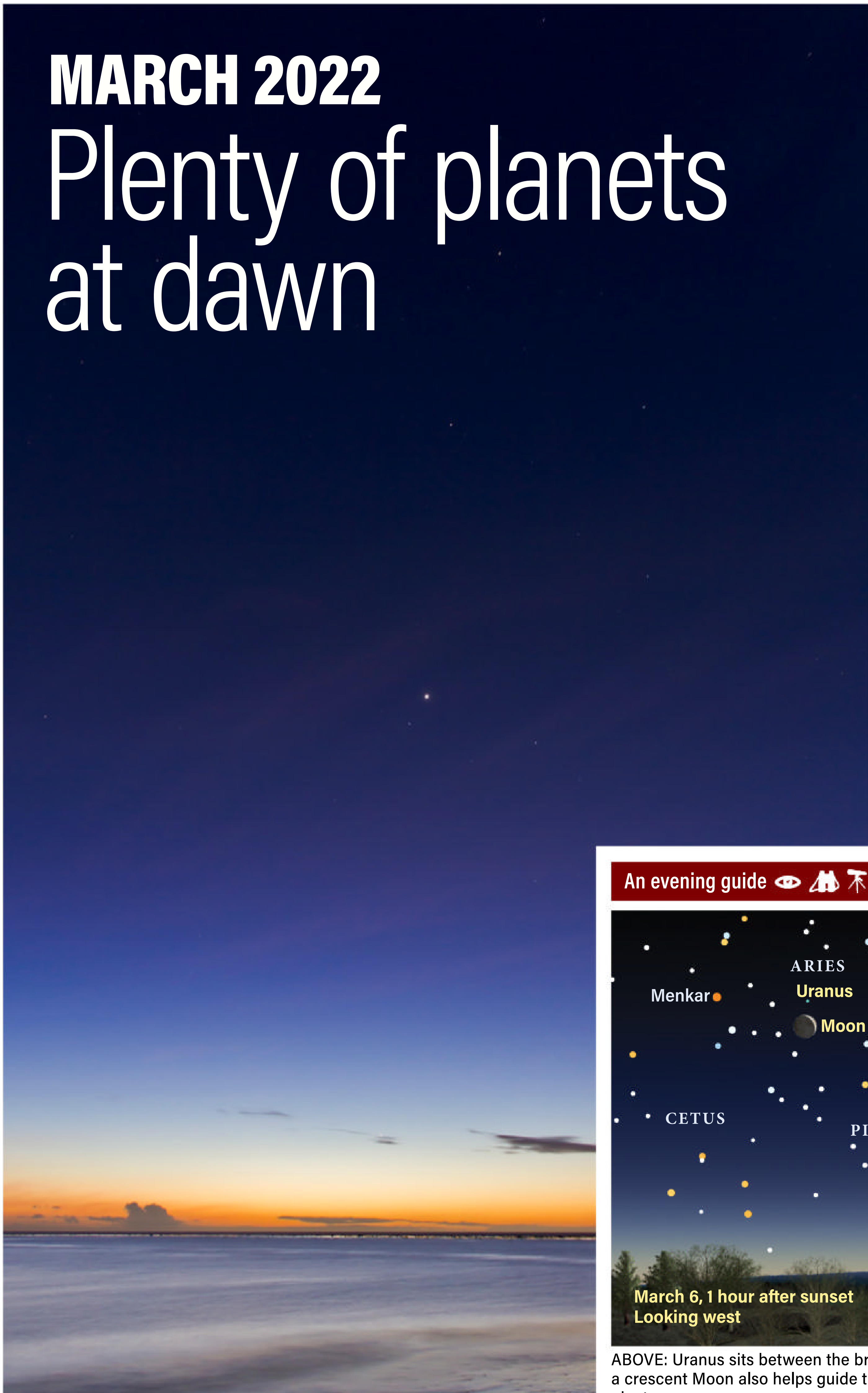
Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.

BY MARTIN RATCLIFFE AND ALISTER LING

MARCH 2022

Plenty of planets at dawn



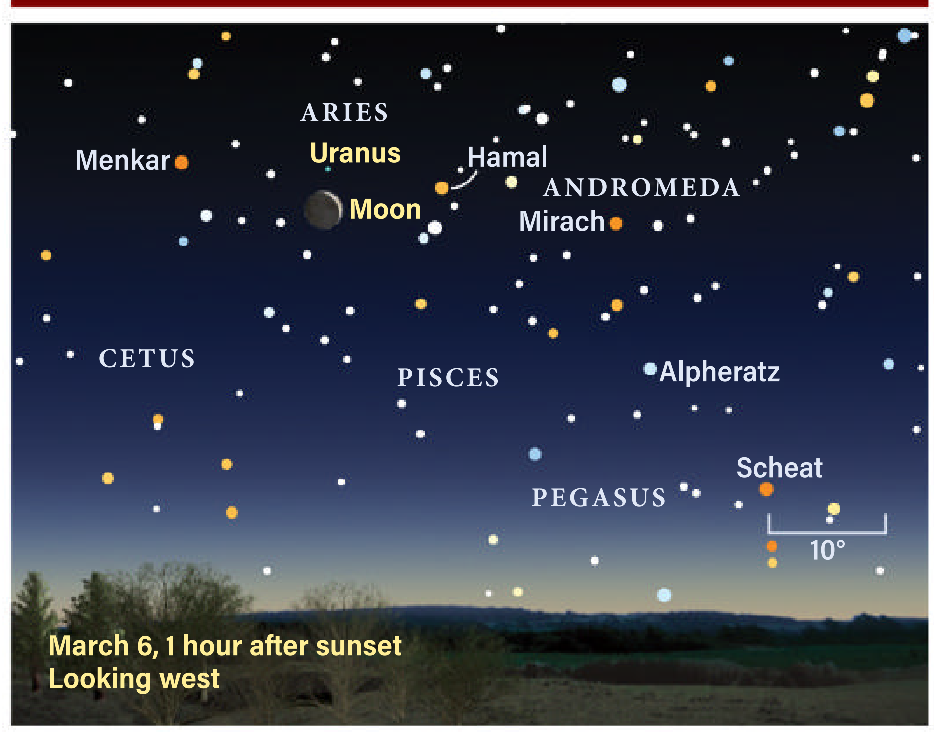
Venus continues to dominate in the morning, along with a retinue of fellow planets gracing the predawn sky. Mars, Saturn, and elusive Mercury provide lots to observe. Jupiter largely is hidden from view after its conjunction with the Sun. Meanwhile, the evening sky carries William Herschel's great discovery of 1781, the planet Uranus, easily visible in binoculars.

Let's start with a closer look at this distant giant. The only planet visible in the evening sky is 6th-magnitude **Uranus**, nestled within a dim region of Aries the Ram. It stands due north of the circle of stars depicting the head of Cetus the Whale.

The easiest way to find the field of view containing Uranus as you scan around with binoculars is to draw a line

LEFT: Mercury, Venus, Mars, and Saturn share the sky in July 2010. This month, the same planets appear in the morning twilight, with Mercury ducking out early and Jupiter joining in late March. ALAN DYER

An evening guide



ABOVE: Uranus sits between the bright stars Menkar and Hamal. On March 6, a crescent Moon also helps guide the way, hanging just southwest of the ice giant. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

MERCURY and **SATURN** stand 42" apart the morning of March 2. Try to catch them in the half-hour before sunrise.

between Hamal, the brightest star in Aries, and Menkar, the brightest star in Cetus. Uranus lies midway between these two easy-to-spot 2nd-magnitude stars.

Once you're in the right vicinity, look for a pair of stars within the field of view of 7x50 or 10x50 binoculars. The two stars you're looking for are Omicron (ο) Arietis and 29 Arietis, both about 6th magnitude and separated by 2.8°. Uranus wanders

— Continued on page 38

RISING MOON | More hopeful by the day

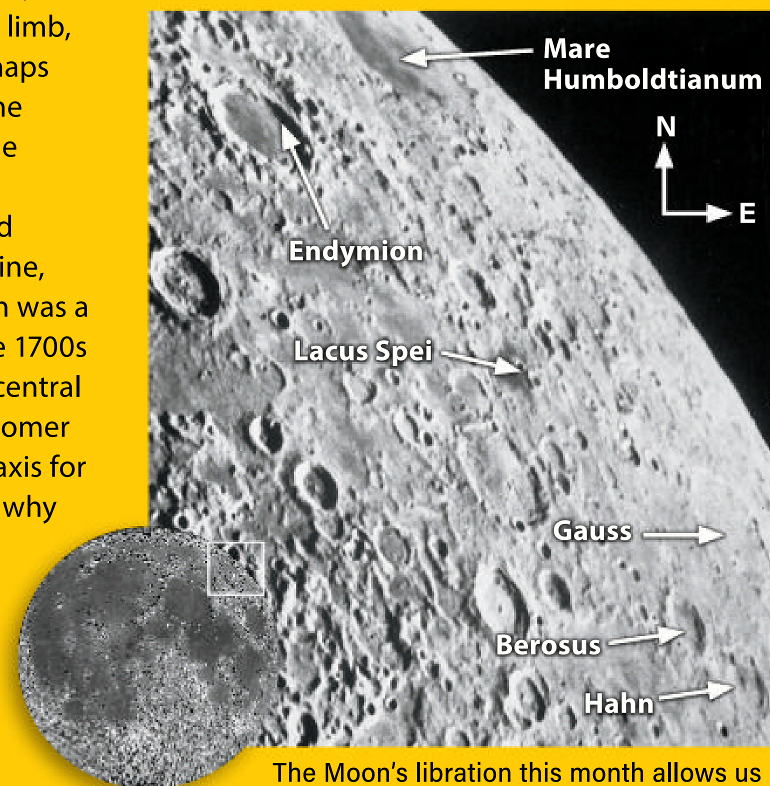
SPRING CRESCENTS ARE THE BEST! With the Moon standing high above the horizon, you've got time to explore Luna's eastern limb, where shadows abound. On the 3rd, perhaps the only recognizable features north of the equator are Mare Humboldtianum and the 110-mile-wide Gauss.

Come back on the 4th to see Hahn and Berosus sporting bright rims in the sunshine, their bowls in shadow. Friedrich von Hahn was a dedicated amateur astronomer in the late 1700s who discovered the Ring Nebula's (M57) central star. Berosus was a 3rd-century B.C. astronomer who realized the Moon spun once on its axis for each revolution around Earth, explaining why we always see the same face.

Lacus Spei, the Lake of Hope, has tasted morning Sun by the 5th. It's about halfway between Gauss and the notable flat-floored Endymion. Can you see Spei's splotch? Perhaps not with the mixed shadowed terrain, but in a few nights its darkness will stand out. It might be an old mare that never got covered, or the sooty apron from a shallow volcanic cone.

A dynamic phenomenon to watch is the night-by-night backward tilt of Gauss and Humboldtianum away from us and toward the limb, which occurs from the 4th through the 10th. The Moon does not really rock like that — it's a trick of perspective when our satellite climbs above the ecliptic and bares its underside. This libration also lets us see more of the west and less of the east because the Moon is in a slower part of its orbit, letting its constant turning get ahead.

Lacus Spei and more



The Moon's libration this month allows us a fine view of features in the lunar west. CONSOLIDATED LUNAR ATLAS/UA/LPL. INSET: NASA/GSFC/ASU

METEOR WATCH | Focus on the sky

Chance sighting

A sporadic meteor that is not associated with a shower streaks across the sky in July 2020. ROCKY RAYBELL

FOR THE SECOND MONTH in a row, no major meteor showers occur. This offers two opportunities for observers. One is looking for the background, or sporadic, meteor rate. The best times this month occur during the dark Moon period beginning March 1. A First Quarter Moon on March 9 sets before 2 A.M. local time, offering dark morning skies. Sporadic rates average a half-dozen meteors per hour. Morning skies are best because you're on the leading hemisphere of Earth as we orbit the Sun, so meteors strike the atmosphere head-on. Evening rates tend to be lower as we look back along our orbit, as if viewing out the rear-facing window of planet Earth, so meteors have to catch up with us.

The second opportunity for observers this month is viewing the zodiacal light in the evening sky. Your best chances are the first few days of March before the Moon interferes and the last week of the month, when again the Moon is out of the way.

Zodiacal light comes from sunlight reflecting off fine dusty debris littering the inner solar system. This is the detritus left by ancient comets. Once twilight has faded, look for a delicate cone-shaped glow extending above the western horizon. You'll need a very dark moonless sky with no interfering lights. The zodiacal light is aligned with the ecliptic, Earth's orbital plane, and passes through Pisces, Aries, and Taurus. Try using peripheral vision to spot the arching cone of light by scanning left to right along the horizon.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. March 1
10 P.M. March 15
9 P.M. March 31

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

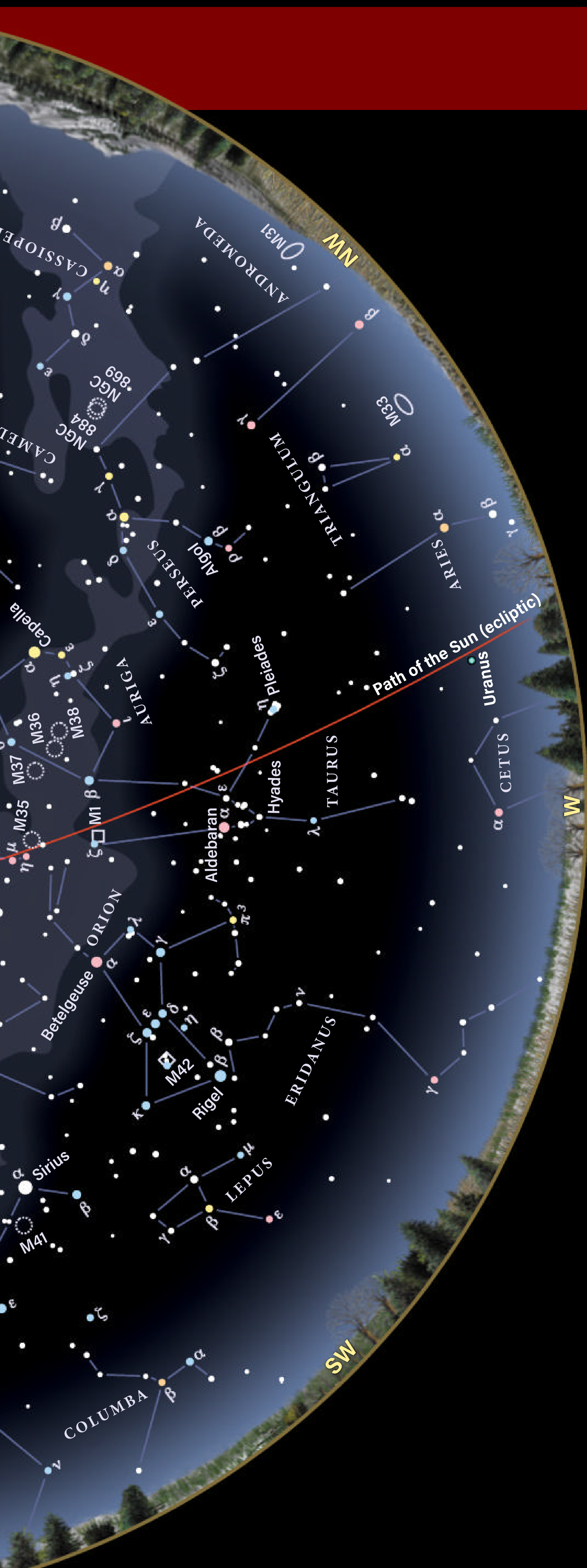
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



MARCH 2022

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

2 Mercury passes 0.7° south of Saturn, 8 A.M. EST

New Moon occurs at 12:35 P.M. EST

5 Jupiter is in conjunction with the Sun, 9 A.M. EST

7 The Moon passes 0.8° south of Uranus, 1 A.M. EST

9 The Moon passes 0.3° south of dwarf planet Ceres, 2 A.M. EST

10 First Quarter Moon occurs at 5:45 A.M. EST

The Moon is at apogee (251,200 miles from Earth), 6:04 P.M. EST

12 Venus passes 4° north of Mars, 9 A.M. EST

13 Neptune is in conjunction with the Sun, 8 A.M. EDT

18 Full Moon occurs at 3:18 A.M. EDT

20 Venus is at greatest western elongation (47°), 5 A.M. EDT

Vernal equinox occurs at 11:33 A.M. EDT

Mercury passes 1.3° south of Jupiter, 6 P.M. EDT

23 The Moon is at perigee (229,758 miles from Earth), 7:37 P.M. EDT

25 Last Quarter Moon occurs at 1:37 A.M. EDT

27 The Moon passes 4° south of Mars, 11 P.M. EDT

28 The Moon passes 7° south of Venus, 6 A.M. EDT

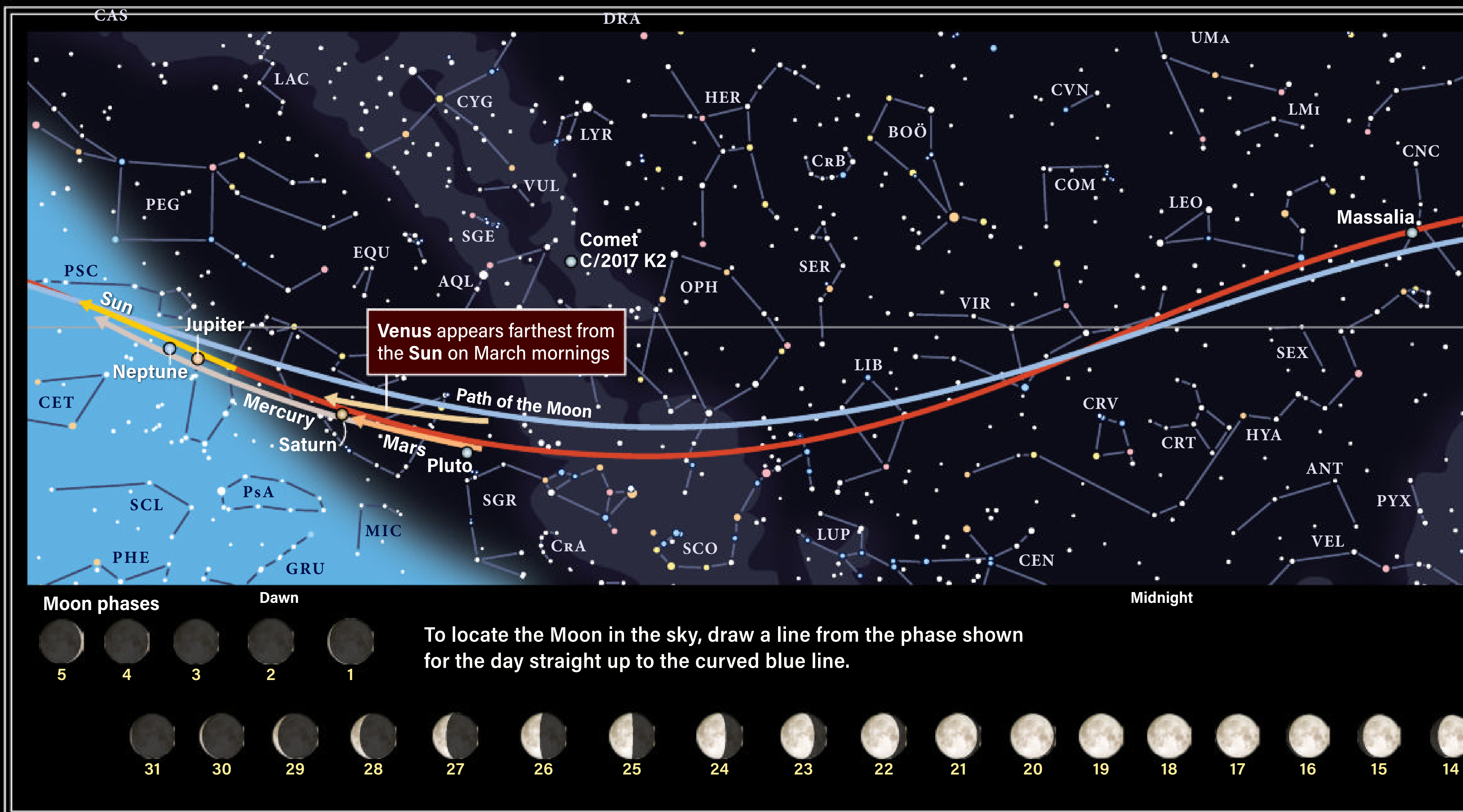
The Moon passes 4° south of Saturn, 8 A.M. EDT

29 Venus passes 2° north of Saturn, 9 A.M. EDT

30 The Moon passes 4° south of Jupiter, 11 A.M. EDT

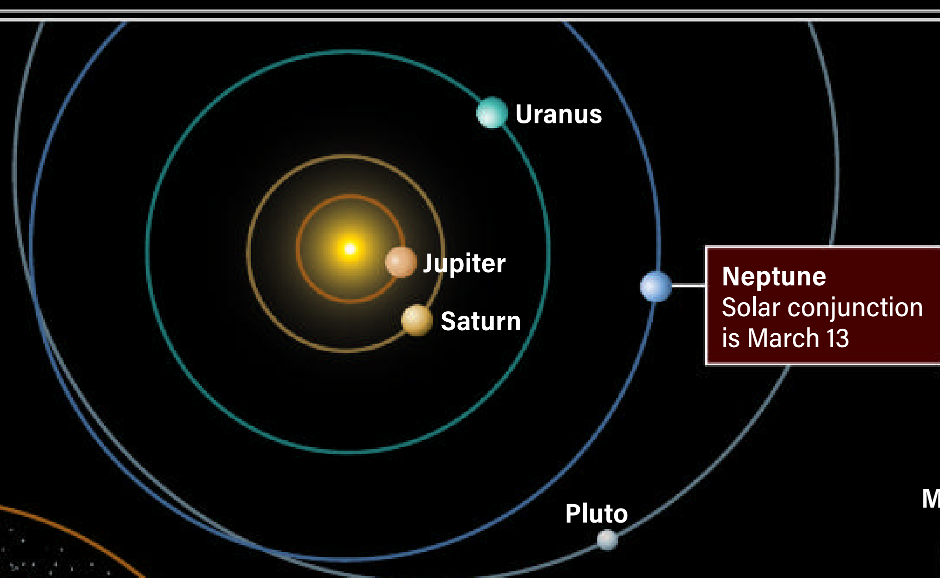
The Moon passes 4° south of Neptune, 3 P.M. EDT

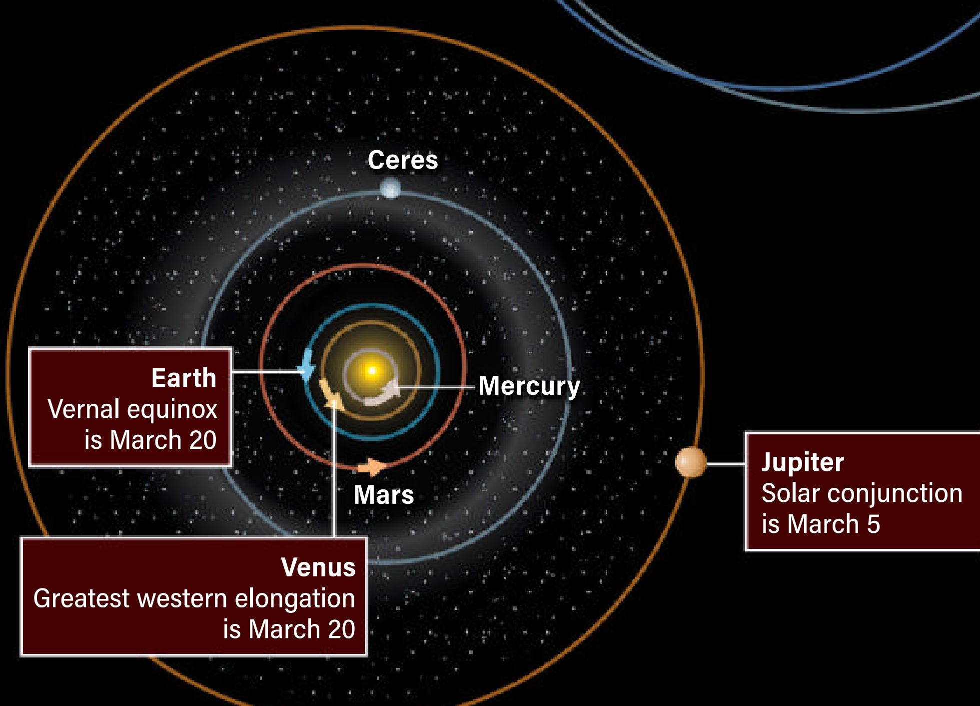
PATHS OF THE PLANETS



THE PLANETS IN THEIR ORBITS

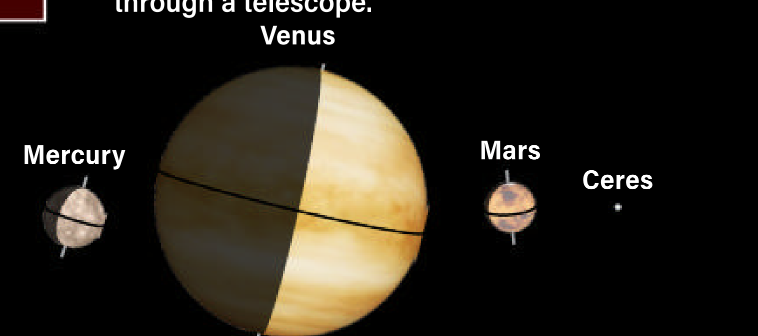
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.





THE PLANETS IN THE SKY

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.

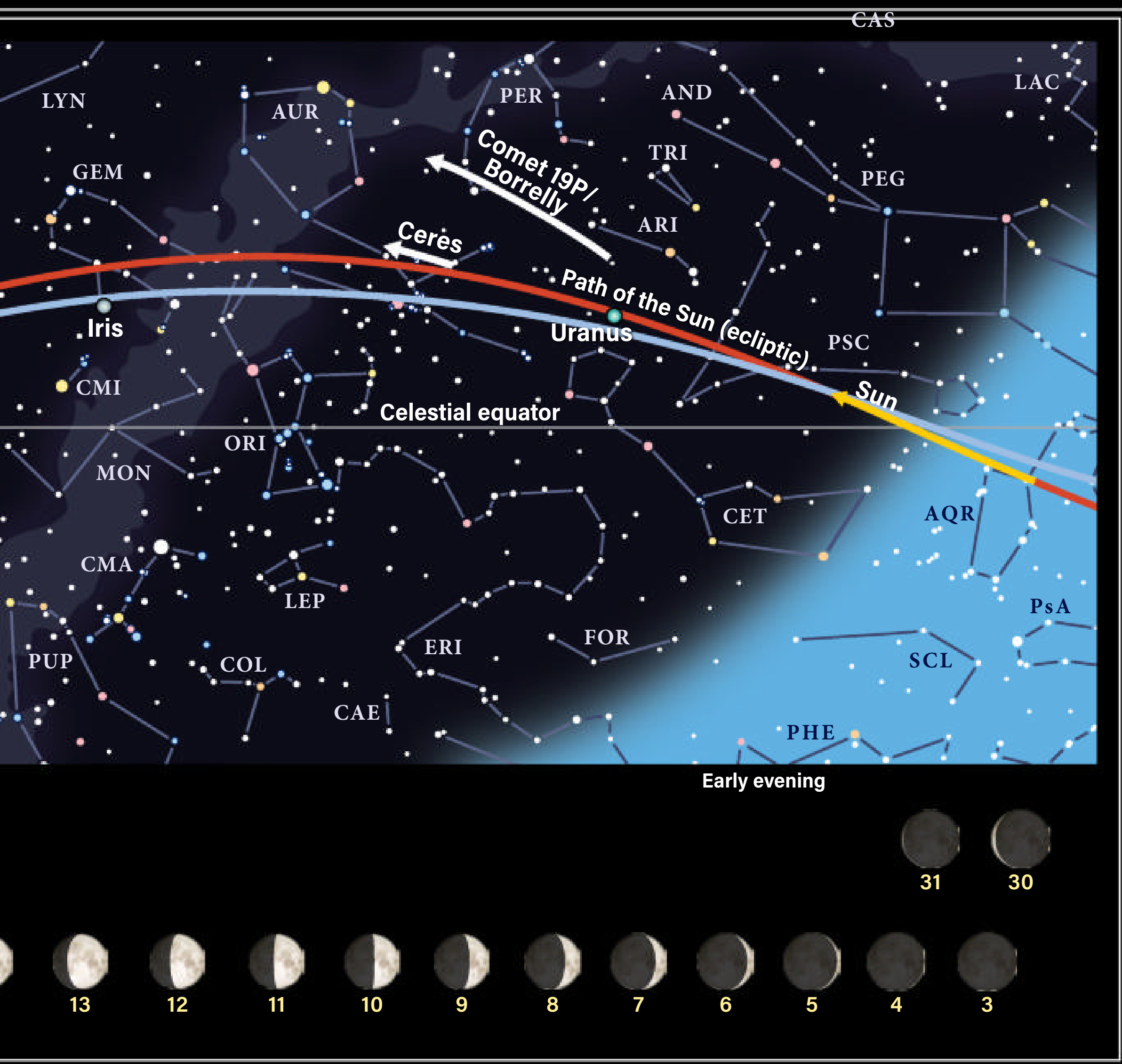


PLANETS	MERCURY	VENUS
Date	March 1	March 15
Magnitude	–0.1	–4.6
Angular size	5.9"	26.2"
Illumination	76%	47%
Distance (AU) from Earth	1.148	0.636
Distance (AU) from Sun	0.467	0.723
Right ascension (2000.0)	21h16.9m	20h37.5m
Declination (2000.0)	–17°16'	–15°49'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

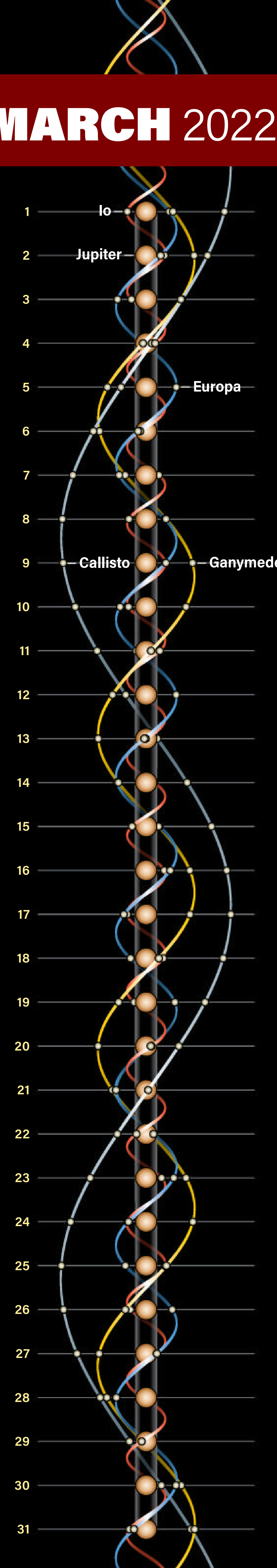
JULY 2021

MARCH 2022

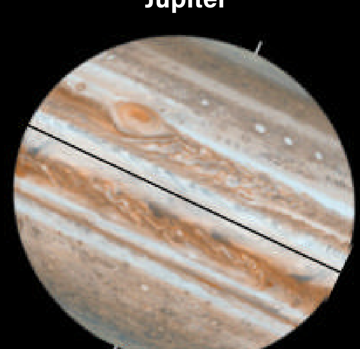


JUPITER'S MOONS

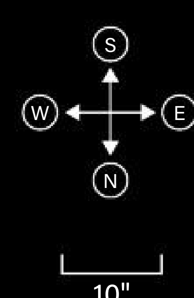
Dots display positions of Galilean satellites at 7 A.M. EDT on the date shown. South is at the top to match the view through a telescope.



Jupiter



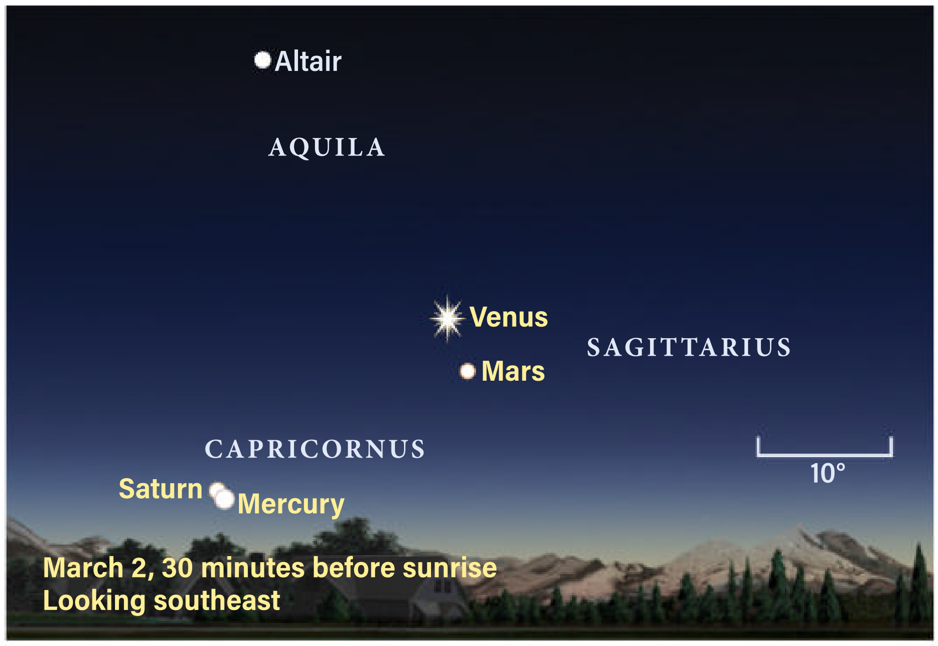
Saturn



Uranus Neptune Pluto

MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
March 15	March 15	March 31	March 15	March 15	March 15	March 15
1.2	8.7	–2.0	0.7	5.9	7.8	15.2
4.9"	0.5"	33.4"	15.5"	3.5"	2.2"	0.1"
93%	97%	100%	100%	100%	100%	100%
1.909	2.768	5.908	10.712	20.368	30.913	35.024
1.444	2.661	4.976	9.904	19.712	29.919	34.482
20h35.5m	4h21.9m	23h27.6m	21h31.0m	2h37.9m	23h34.7m	20h01.1m
–19°41'	23°02'	–4°35'	–15°40'	15°01'	–3°57'	–22°25'

Close encounter



Mercury is visible early in the month. Catch it standing just 42" south of Saturn on the 2nd.

northeastward during March, starting from a point 44' southeast of 29 Ari. The planet will appear slightly bluish under good transparent skies.

A useful guide is the waxing crescent Moon, which sits in Aries March 6 — a lovely sight in the evening sky. Swing your binoculars between 3° and 4° northeast of our satellite to find Uranus.

From March 14 to 23, Uranus stands within 18' of a 7th-magnitude red giant field star, and their color contrast is noticeable. It's an especially fine view using an APO refractor, which has good color rendition. Notice the brighter blue supergiant, Omicron, standing just over 1° to the east. For the remainder of March, Uranus heads toward Omicron, ending the month 0.8° due west of the star.

Switch to a telescope to view Uranus' distinctive bluish-green disk, which spans just over 3". This distant giant lies 1.9 billion miles from Earth.

To observe more planets, set your alarm early to catch a spectacular show in the predawn sky, starring Venus, Saturn, and Mars.

The spring equinox occurs March 20 at 11:33 A.M. EDT.

Venus is first up in the morning sky, rising more than two hours before the Sun March 1st. **Mars** rises within half an hour of Venus, and the two stand 5° apart in eastern Sagittarius. Venus is dazzling at magnitude –4.7, while Mars is a relatively dim magnitude 1.3. Over the month, Venus dims to magnitude –4.4 and Mars brightens to magnitude 1.1.

Mars appears as a glowing, amber-colored jewel compared with the stunning white sapphire glow of Venus. They trek in tandem across Sagittarius, reaching Capricornus March 6. You'll find them 3.9° apart — their closest — March 15. Venus' continued daily drift against the backgrounds stars remains faster than Mars'. The brilliant planet soon forms the apex of a triangle with Mars and **Saturn**, which lies farther east and glows at magnitude 0.7 all month.

Venus reaches its greatest elongation on March 20, when it stands 47° west of the Sun. Check it out with a telescope to reveal a 50-percent-lit disk spanning 25". Due to the Schröter effect, reported in the 1790s by German astronomer Johann Schröter, the visual

WHEN TO VIEW THE PLANETS

EVENING SKY
Uranus (west)

MORNING SKY
Mercury (east)
Venus (southeast)
Mars (southeast)
Jupiter (east)
Saturn (east)

COMET SEARCH | Goin' to California

TAKE ADVANTAGE of two dark-sky windows to view the departing Comet 19P/Borrelly. The comet starts off March near the magnitude 3.6 guidepost 41 Arietis, halfway between the Pleiades (M45) and the familiar hockey stick shape of Aries. Glowing at 10th magnitude, Borrelly will be a fair bit dimmer than M1 far to its southeast — the object that started comet hunter Charles Messier on his journey to creating the *Catalogue of Nebulae and Star Clusters*.

Tough for a 4-inch scope, the ball of dust and ice will be within reach of a 6-inch aperture under dark skies. At powers above 150x, the north limb of the inner coma will be sharply defined, hiding the actual nucleus from sight, while a stubby fan diffuses out to the south. The Moon interferes for the middle two weeks of the month.

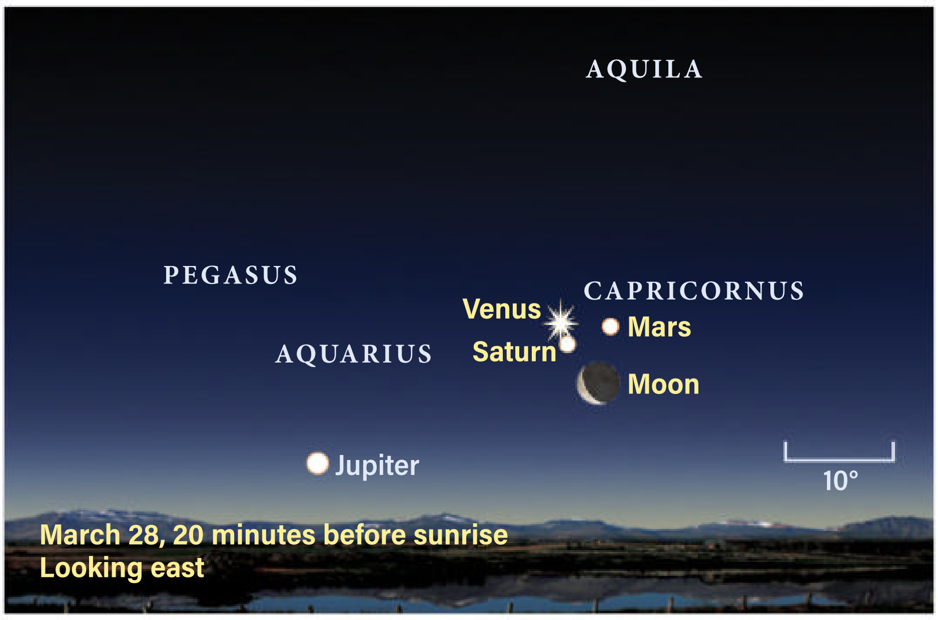
Sporting a period of 6.8 years, Borrelly returns as a binocular comet with a very favorable apparition in December 2028.

And there's more! The photogenic field between M35 and the Rosette Nebula (NGC 2237) hosts two fainter comets: 104P/Kowal and C/2019 L3 (ATLAS). Comet 67P/Churyumov–Gerasimenko is nearby in Cancer. Visual observers will want to switch to the brighter C/2017 K2 (PanSTARRS) in Aquila after midnight.

Comet 19P/Borrelly

Wide-field astroimagers get a nice treat starting March 25, when Comet Borrelly slides less than 2° south of the California Nebula (NGC 1499). It sits on the state's southern border the 27th.

Twilight portrait



The Moon and planets are out to play by March 28 — including Jupiter, which sits low in twilight. Those with a clear eastern horizon may spot it.

moment of dichotomy (when the planet is 50 percent lit) appears later than predicted during morning apparitions. This is likely a combined effect of the refraction of light through the upper clouds of Venus combined with perception effects by the visual observer. When do you observe dichotomy?

On March 24 and 25, Venus is roughly equidistant (4° to 5°) from Mars and Saturn. The elegant triangle of planets stands 8.5° high an hour before sunrise. A waning crescent Moon lies in Sagittarius on the 25th.

The best scene of the month occurs March 28, when a 26-day-old crescent Moon joins the planetary trio. Our satellite stands 6° below Mars, while Saturn and Venus are 2.2° apart 6° north of the Moon. It's a stunning spectacle that's exciting to follow as twilight proceeds. Grab some photos of this elegant morning scene and enhance it with suitable silhouette features such as a windmill, trees, or stylish buildings.

A visual treat awaits the observer with a telescope. Venus spans 23" and now displays a 54-percent-lit disk. Saturn's 16"-wide globe, surrounded by its famous rings, provides dramatic contrast. Mars remains a tough observational target (and will for some months), spanning a mere 5".

Try following Venus into daylight, when you can achieve better views of its cloud tops by avoiding the glare that occurs when it's in a darker sky. On March 31, Venus and Mars are 6° apart, with Saturn now neatly situated between them.

Mercury remains visible in early March. You can catch it just 42" south of Saturn on March 2 when they rise shortly before 6 A.M. local time. Mercury shines at magnitude –0.1, brighter than Saturn. Try to spot the pair 30 minutes after they rise, when they stand 6° above the eastern horizon. Venus lies 22° farther west along the ecliptic, already 20° high.

Mercury quickly descends deeper into twilight and becomes harder to spot. Can you see it 2° high on March 9, just 20 minutes before sunrise? Soon after this, Mercury disappears, continuing toward its early April superior conjunction. Meanwhile, Saturn climbs higher each morning.

Jupiter reappears briefly in the morning sky at the end of the month, following its March 5 conjunction with the Sun. See if you can spot the magnitude –2.0 planet at the end of the month, standing just 2° high in the eastern sky in the 30 minutes before dawn. Telescopic viewing of the giant planet will have to wait a month or two. Venus, Saturn, and Mars stand 10° higher in the southeast.

The spring equinox occurs March 20 at 11:33 A.M. EDT. It's the transition from northern winter to spring, offering equal sunlight in both hemispheres.

Neptune reaches conjunction with the Sun March 13. It is not visible this month.

***Martin Ratcliffe** is a planetarium professional with Evans & Sutherland and enjoys observing from Wichita, Kansas. **Alister Ling**, who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

LOCATING ASTEROIDS

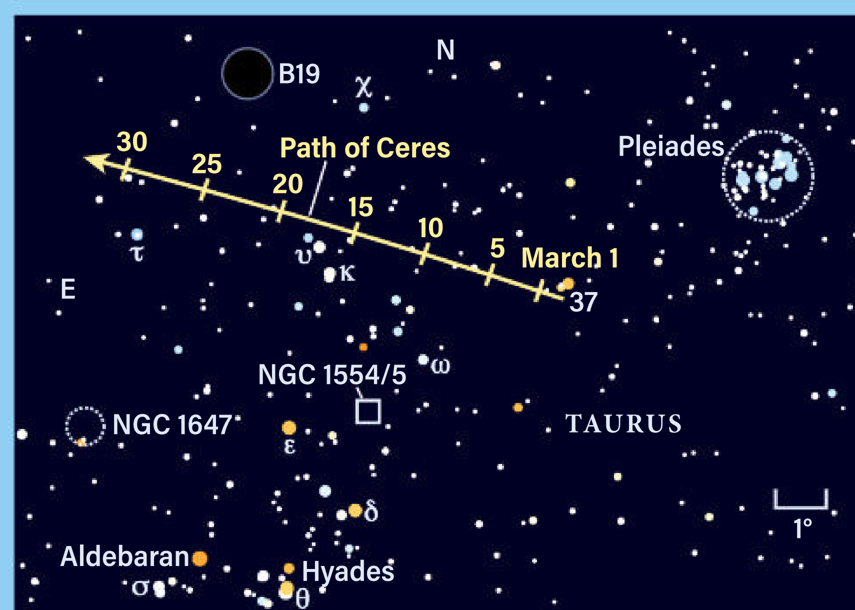
Climbing the horns of the Bull

HIGH IN THE SOUTHWEST, ruddy Aldebaran seems to keep an eye on the ruler of the asteroid belt climbing up Taurus' northern horn. Dwarf planet 1 Ceres remains a straightforward target for a 60mm refractor from the suburbs, even as it slowly fades out of binocular reach.

On its inside track around the Sun, Earth overtook Ceres a few months ago, leaving it to travel eastward on a straight path near the ecliptic. Halfway between the Hyades and Pleiades, Ceres lies near the magnitude 4.4 star 37 Tauri. In this younger section of the Milky Way, the dichotomy of faint and bright stars provides recognizable patterns for you to latch onto. To watch the dwarf planet shift spots in one observing session, use it as a third point of some notable triangle and note how the shape morphs after a three-hour span.

If you're at the Crab Nebula (M1) during a Messier marathon at month's end, pop up to the field just north of Tau (τ) Tauri, nab Ceres, and watch the stars vanish into the trench of dark nebula Barnard 19, an envelope for several smaller and deeper dust clouds.

Through dark and light



Ceres travels up the star-studded face of Taurus the Bull this month.

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

A key figure in the development of the Nazi rocket program, Wernher von Braun became director of NASA's Marshall Space Flight Center in 1960. NASA/MSFC

WHEN THE ATOMIC AGE MET THE SPACE AGE

Is space for exploration or militarization? Early rocket pioneers like Wernher von Braun thought it might be prudent to pursue both. BY FRED NADIS

THE SPACE FORCE, a new branch of the U.S. military with an insignia shaped much like a *Star Trek* communicator, was launched in December 2019 with a continuing mission "to protect U.S. and allied interests in space." To justify the establishment of the Space Force, military planners and members of its predecessor, Air Force Space Command, frequently offer the mantra: "Space is no longer a benign environment."

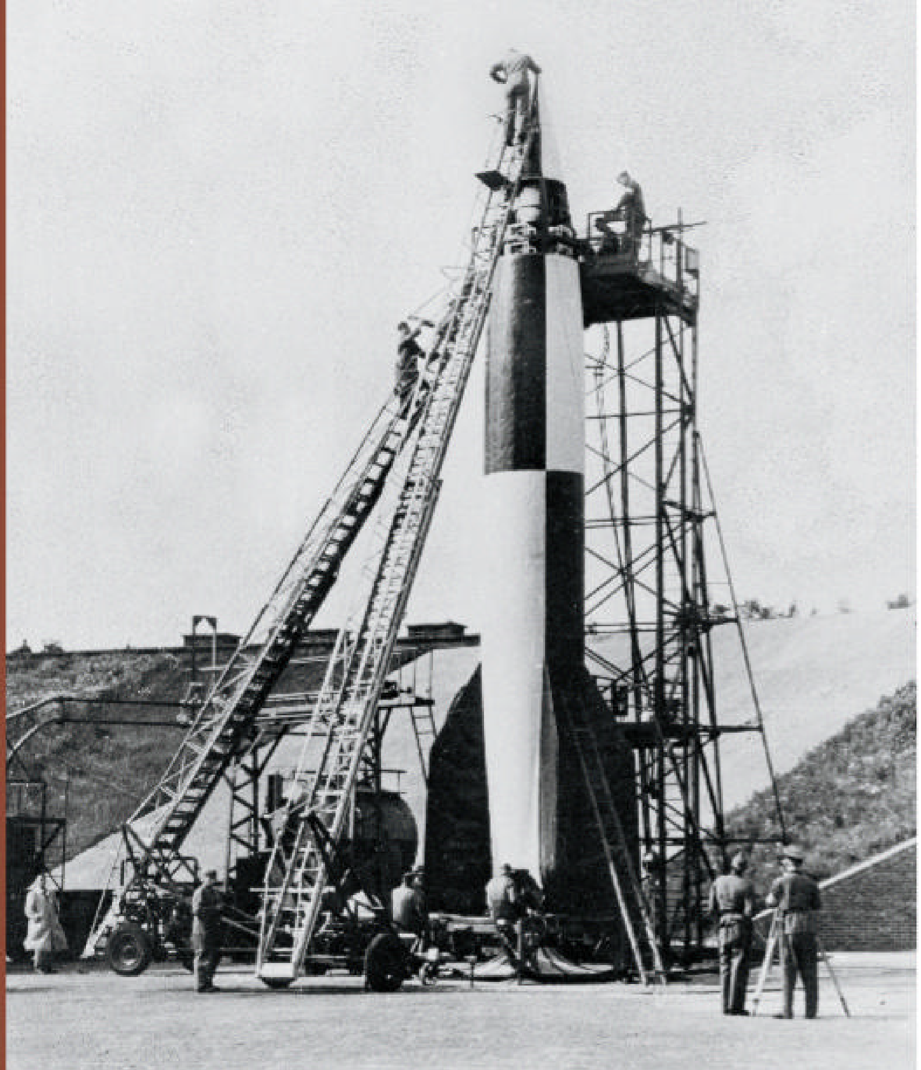
But space has never been a benign environment — and not just because of the bug-eyed monsters imagined by early science fiction writers. While robotic rovers on Mars symbolize our thirst for scientific knowledge and the International Space Station exemplifies international cooperation, peaceful and purely scientific pursuits in outer space have always contended with militaristic ambitions. And no one better embodied the tension between militarism and the high ideals of spaceflight than Wernher von Braun.

From V-2s to space stations

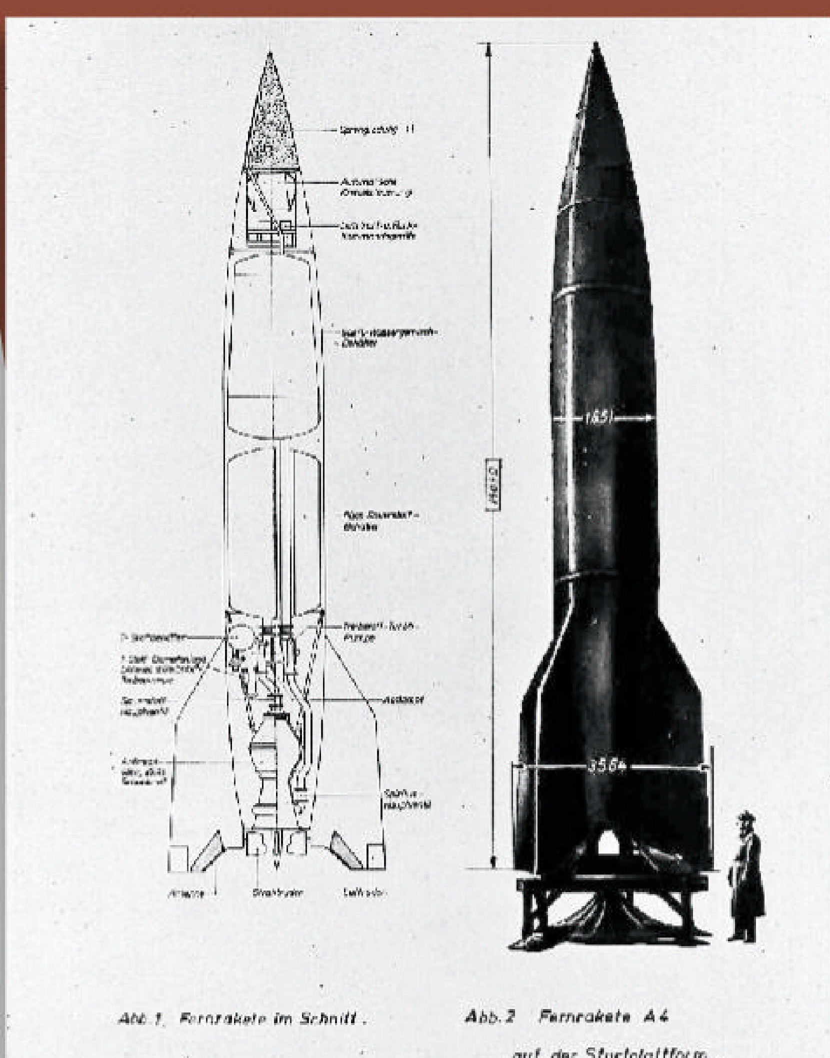
As a teenager in the 1920s, von Braun was inspired by German-Romanian space visionary Hermann Oberth's description of humans leaving the planet to explore the solar system. Pursuing this goal, in the 1930s and 1940s von Braun led the design of the Nazi V-2 rockets, the world's first long-range guided missiles. These rockets, however, did not help the Nazis explore space; they exploded in London and Antwerp during the last months of World War II, killing about 5,000 people. But for von Braun, missile design was a prelude; outer space exploration awaited. After his surrender to the U.S. Army in Germany in 1945, he and his engineers intrigued interrogators with visions such as erecting giant mirrors in space that would be able to change the weather or incinerate cities.

There was just one problem:

President Donald J. Trump unveiled the seal of the U.S. Space Force via Twitter, on Jan. 24, 2020.
U.S. SPACE FORCE



German technicians work to stack the stages of a V-2 rocket, the world's first long-range guided ballistic missile, in this undated photo. Following World War II, von Braun, along with a number of other captured scientists and engineers who worked on the V-2 program, were brought to the U.S. to work at Fort Bliss in Texas and Redstone Arsenal in Huntsville, Alabama. NASA/MSFC



These German drawings depict the Aggregat 4 (A-4), later renamed the V-2. The cross-section at left highlights the rocket's internal workings, while the view at right shows its dimensions. The V-2 stood 45 feet (15 m) tall and 5.5 feet (1.65 m) wide. NASA

In the immediate post-war America that the ex-Nazi engineers were whisked away to, spaceflight was still widely seen as science fiction. Von Braun's new day job was to design missiles for the U.S. Army. But in his spare time, he sought to shift the public's opinion. He wrote a highly technical novel about a journey to Mars that failed to find a publisher. From 1952 to 1954, with the help of splashy color illustrations, he and a panel of other experts provided a glimpse of the impending Space Age in *Collier's* magazine, presented as an eight-part series titled "Man Will Conquer Space Soon." From 1955 to 1957, von Braun also helped shape Walt Disney's three-part television film series on space exploration, starting with the episode "Man in Space."

In the *Collier's* series, von Braun insisted that an orbiting space station was a critical first step for space exploration. The spoked-wheel-shaped station, which later inspired the one in Stanley Kubrick's *2001: A Space Odyssey*, would be 250 feet (76 meters) wide, useful as a scientific base, for surveillance, and for staging ventures to the Moon and Mars. It could spin every 12.3 seconds to simulate Earth gravity, or it could spin every 22 seconds to create artificial gravity at one-third that on Earth — similar to that on Mars. The space station would orbit 1,075 miles (1,730 kilometers) above Earth and circle the planet every two hours at 15,840 mph (25,490 km/h). It would be visible from the ground "as a fast-moving star." Although von Braun noted that the station, with an estimated cost of $4 billion, could end up "uniting mankind," his plan wasn't benign.

In the Collier's series, von Braun insisted that an orbiting space station was a critical first step for space exploration.

To help justify this costly effort, von Braun insisted that builders would stock the space station not just with scientific equipment but also nuclear weapons. President Harry S. Truman and staff had turned to nuclear deterrence as the most cost-effective method to keep the Soviet Union in check. Capitalizing on this strategy, von Braun told military audiences, "If we can … establish our artificial satellite with its space-to-ground missiles ready for action, we can stop any opponent cold in his attempt to challenge our fortress in space!" Guided

by radar and striking at supersonic speed, space-based nuclear-armed missiles would be deadly and, von Braun claimed, accurate. The Cold War would be over. *Collier’s* editors supported this plan, noting, “A ruthless foe established on a space station could actually subjugate the peoples of the world. … In other words: whoever is the first to build a station in space can prevent any other nation from doing likewise.”

Space for science?

President Dwight D. Eisenhower offered a more moderate vision of the advance into space. In 1958, he proposed to Congress that NASA be established under civilian control, with the aim that “outer space be devoted to peaceful and scientific purposes.” But Eisenhower also made the Department of Defense responsible for “space activities peculiar to or primarily associated with military weapons systems or military operations.” Eisenhower’s dual approach indicated that exploration and the military use of space were not easily separated: Space-based surveillance and communication had both military and peaceful applications, and the same rockets that launched satellites could be armed as missiles. In fact, ballistic missiles, in their parabolic flights, have the potential to reach altitudes of thousands of miles, well past the Kármán line 62 miles (100 km) up, which generally denotes the ill-defined border of outer space.

German rocketeers (left to right) Walter Dornberger, Herbert Axster, von Braun, and Hans Lindenberg are seen here after surrendering to U.S. troops in May 1945. Von Braun had broken his arm in car crash that March. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

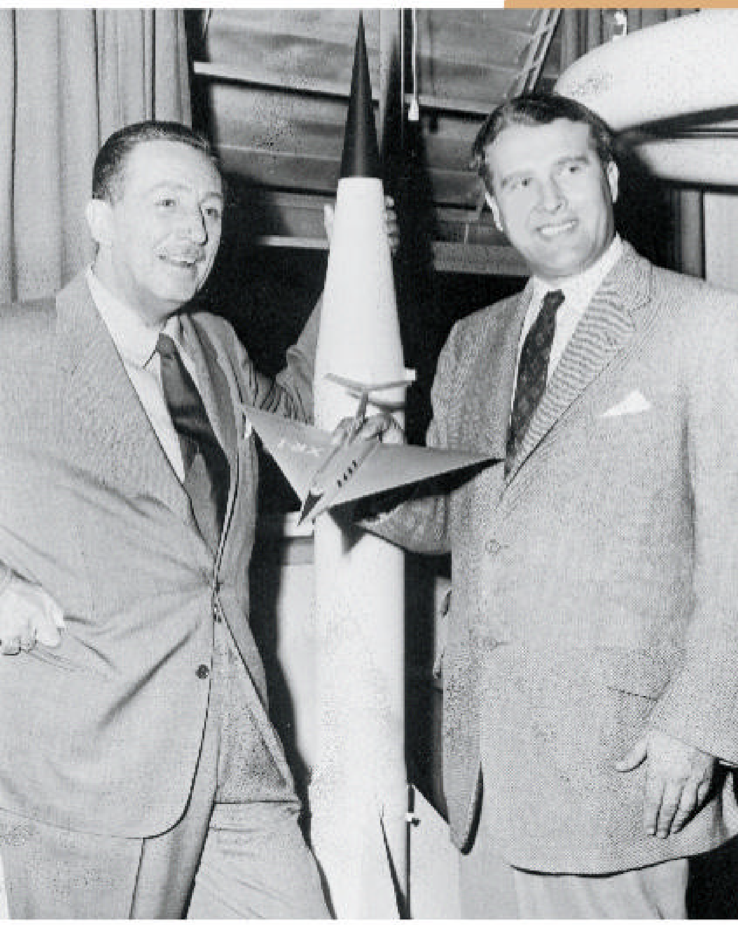
A number of Cold War-era strategists argued that nuclear weapons needn’t be limited to a space station, either. In 1959, Dwight E. Beach, the Army’s director of guided missiles and special weapons, said, “We ought to consider the possibility of Moon-based weapons systems, eventually to be used against Earth and space targets.” The Air Force’s deputy director of research and development, Homer A. Boushey, argued that because missiles launched at the Moon would take about 48 hours to arrive, no Soviet attack on the Moon or Earth would go unanswered, making the base a superb deterrent.

Also in 1959, the U.S. Army developed Project Horizon, a plan for a Moon base that would house scientists and, potentially, nuclear missiles. To build Horizon, however, would have required 149 launches, as well as another 64 launches in its first year to maintain the base. The cost: $6 billion at the time, which equates to over $54 billion today.

Eisenhower not only rejected Project Horizon, but questioned the strategic value of any nuclear weapons in space. His Science Advisory Committee had reported in March 1958 that while reconnaissance and communication from spaceflight would have

ABOVE: Marshall Space Flight Center (MSFC) Director Wernher von Braun poses at his desk, which is adorned with rocket models and stands in front of a poster of a lunar lander. First appointed in 1960, von Braun remained director of MSFC until his transfer to NASA Headquarters in 1970. NASA/MSFC

LEFT: Von Braun explains the Saturn V rocket, developed for the Apollo program, to President John F. Kennedy on Nov. 16, 1963, just six days before Kennedy’s assassination. NASA Deputy Administrator Robert Seamans is at left. NASA



LEFT: Von Braun and Walt Disney pose together during the famed entertainment visionary's visit to Marshall Space Flight Center in 1954. In the 1950s, Disney produced three television films based on space exploration. Von Braun, while working on the Saturn project, also served as technical director for these films. NASA

RIGHT: The March 22, 1952, issue of *Collier's* magazine included several articles written by space experts that detailed von Braun's plans for manned spaceflight. The multi-year series captivated the American public. COURTESY OF RON MILLER

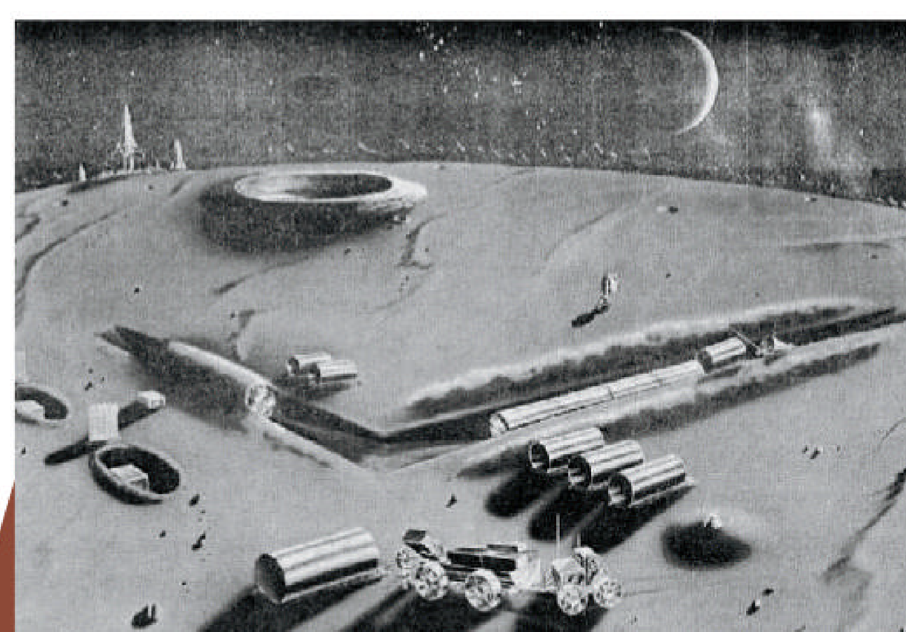
While space currently is free of nuclear weapons, it is stocked with satellites that spy and guide weapons systems on Earth.

important military applications, there was no real value to releasing atomic or other weapons from space. Bombs dropped from a satellite would not simply fall on their targets, but spiral in gradually as their orbits decayed. Even with a rocket to give it the necessary boost, a missile launched from a moving platform in space, though harder to detect, would be far less accurate than an Earth-based one. Indeed, the committee judged the idea "clumsy and ineffective."

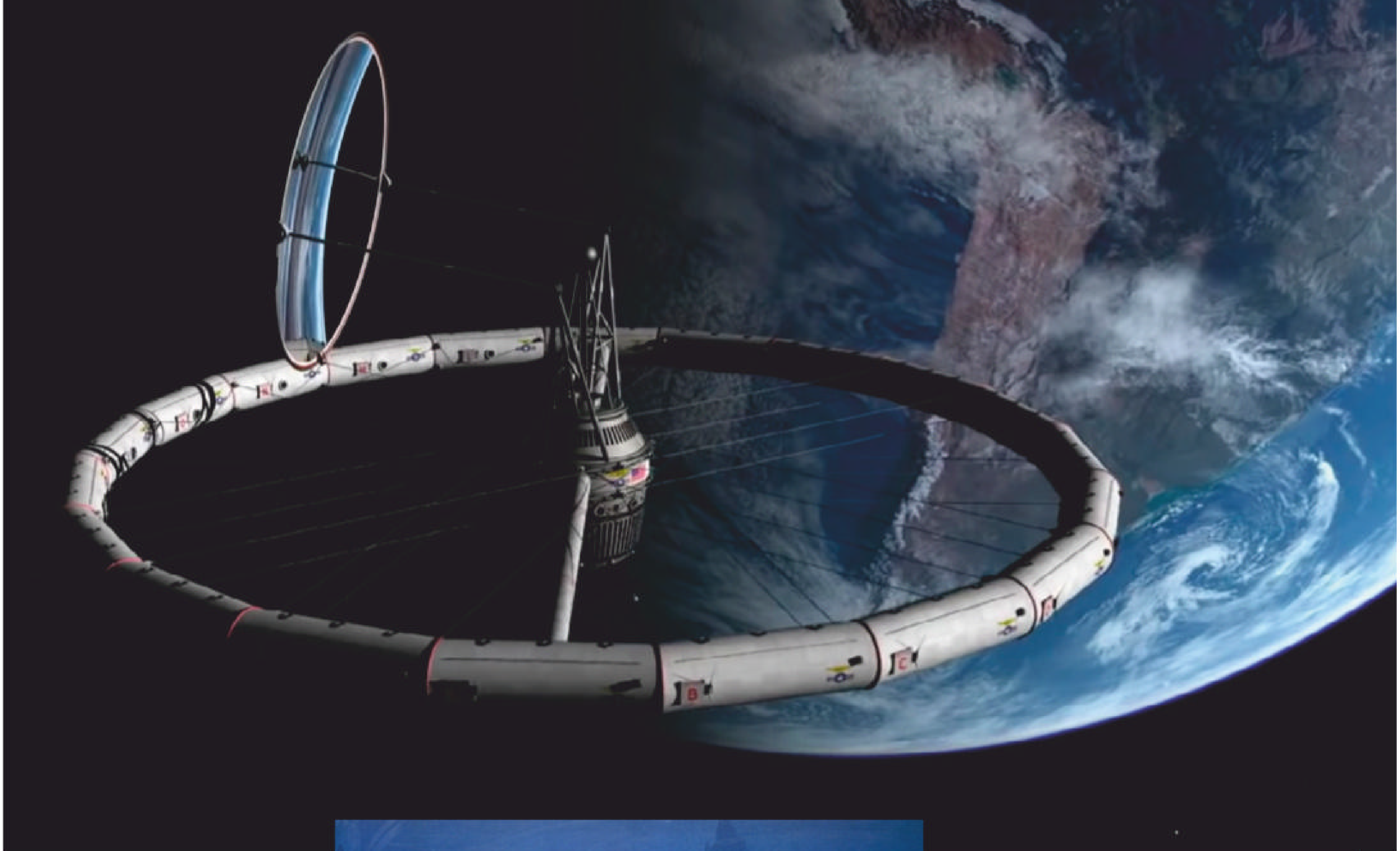
Testifying before Congress that year, von Braun admitted that his earlier vision of a nuclear-armed "space platform" was flawed. Stuck in a fixed orbit, the platform would be "nothing but a housing facility in outer space." He grudgingly agreed with military planners who preferred smaller, maneuverable spacecraft that might orbit Earth a few times with "reconnaissance or even bombing capability."

In the early 1960s, the Soviets began developing just such a weapon, the Fractional Orbiting Bombardment System (FOBS). These nuclear-armed missiles could briefly remain in orbit and pass under the South Pole, making an end run around the United States and NATO's radar network in the Northern Hemisphere. Such orbital bombers could, conceivably, allow Soviets a first strike. The Soviet Union test-launched 24 of these (unarmed) missiles between 1965 and 1971, and did not decommission the armed missiles until several years after the Salt II Treaty banned them in 1979.

Even during this adrenaline-packed phase of the Cold War, a saner vision of space development coexisted with that of the military imagination. David T. Burbach, an associate professor of national security affairs at the Naval War College, explains that a wary consensus grew of space as a "sanctuary, a way to keep an eye on each other, but not the best place for war." The United Nations' Outer Space Treaty, which both the United States and Soviet Union signed in 1967, banned all weapons of mass destruction in space, and insisted that the "moon and



In order to protect U.S. interests, in 1959, the Army explored building a military base, possibly equipped with nuclear weapons, on the Moon. Named Project Horizon, the plan was rejected by Eisenhower. U.S. ARMY



LEFT: In the 1950s, von Braun proposed a ringlike space station, like the one shown in this illustration, that would spin to generate tunable artificial gravity. NASA/MSFC

ABOVE: The spoke-and-wheel-shaped space station von Braun envisioned is gaining steam again. This modern rendering shows a similarly designed station tentatively planned for construction later this decade. GATEWAY FOUNDATION

other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes."

No nukes, but …

The Outer Space Treaty, however, did not ban conventional weapons from space. And, sanctuary or not, in the years that followed, the United States and the Soviets both scrambled for tactical advantage. In 1983, President Ronald Reagan proposed his Strategic Defense Initiative (SDI), which funded research into creating an impenetrable missile shield that would render nuclear missiles obsolete. Billions were spent to research laser and missile systems, including one space weapon that would surround an exploding nuclear device with X-ray lasers — a clear violation of the Outer Space Treaty. Given that the technology behind many of Reagan's plans did not exist yet, it was perhaps unsurprising that his version of the SDI was scrapped in 1993 and replaced by a scaled-down agency with a focus on Earth-based missiles.

While space currently is free of nuclear weapons, it is stocked with satellites that spy and guide weapons systems on Earth. These satellites, in turn, have long been considered strategic targets. The United States, Russia, China, and India have all tested antisatellite missiles. And these nations, along with others, also have developed "non-kinetic" weapons, including signal jammers and land-based lasers that can disrupt satellites. The 2013 film *Gravity* dramatized a major threat from such activity — an exploded satellite generates space debris that litters orbits. While shared concerns over space debris may eventually shape a new consensus, the U.S. government has not yet committed to various international proposals, and a diplomatic resolution to curtail antisatellite weapons is not in sight. Todd Harrison, of the Center for Strategic and International Studies, suggests that for now, "the most promising approach for the U.S. is to build a consensus around norms of behavior in space, define what is normal, what is abnormal."

Meanwhile, the Space Force is here to stay, space exploration and commercial development are flourishing, and von Braun's "platform" is back. U.S. organization the Gateway Foundation is planning an orbiting hotel and spaceport shaped in a "von Braun ring," ready by 2027. The expected cost is $60 billion. And a three-and-a-half-day stay in a deluxe suite will cost roughly $5 million per person.

It will not house nuclear weapons.

Fred Nadis' *most recent book is* Star Settlers: The Billionaires, Geniuses, and Crazed Visionaries Out to Conquer the Universe *(Pegasus Books, 2020).*

Planetary nebulae in COLOR

These dying stars are going out in style, showing off rich greens, blues, and reds you can enjoy through your eyepiece. **BY ALAN GOLDSTEIN**

For new observers, the night sky appears to be a monochrome scene of black and white. Although astronomy books and websites are replete with objects revealing vivid reds, pinks, blues, and greens, gazing at most of these same objects with a small telescope shows none of that. Light from the deep sky appears mostly as shades of gray.

But those of us with more experience know the universe is a colorful place. It's just that color in the universe requires intensity — enough photons to stimulate the cones in your eyes. These color receptors are an evolutionary response to humans spending most of our lives in daylight: When light is plentiful, its subtle differences in wavelength convey useful information, which we perceive as color. By contrast, while the eye's rods are highly sensitive to light to help us see clearly in nocturnal environments, they don't register color.

In the case of the Sun, its many photons at every wavelength saturate all our color receptors at once, making it appear white. And the Moon consists of dark basalts and gray dust and rock fragments — no color there unless there is an eclipse or its light is reddened by Earth's atmosphere as it rises or sets. But looking elsewhere in the solar system, Mars, Uranus, and Neptune show us disks that are intensely red, green, and blue, respectively. And their shape and bright color are duplicated by one group of deep-sky objects: planetary nebulae.

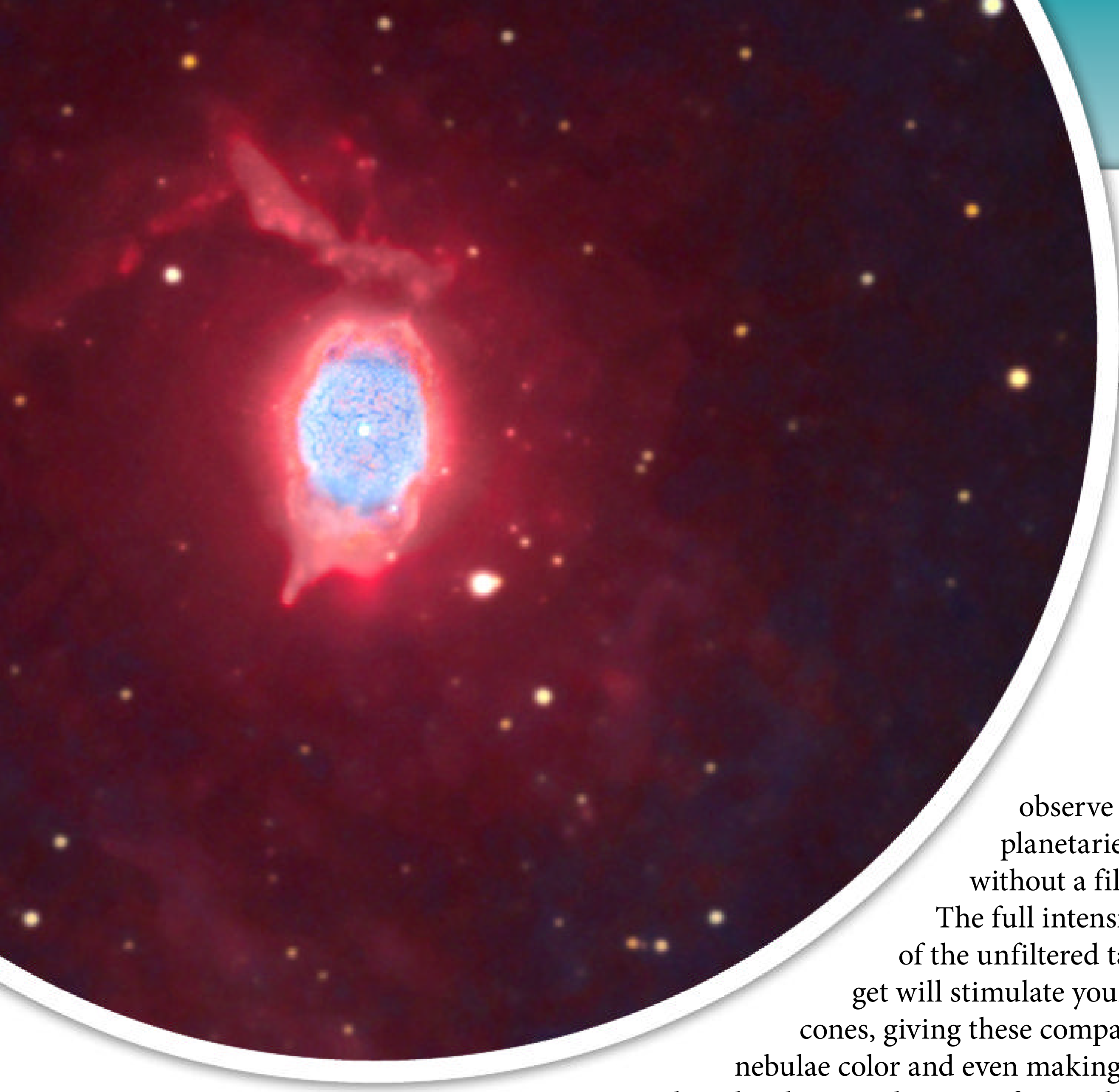
NGC 2392
The compact Lion Nebula (NGC 2392) is surrounded by a fluffy ring of gas akin to the mane framing a big cat's face.
DOUGLAS J. STRUBLE

Colorful targets

Planetary nebulae are the product of Sun-like stars shedding and then lighting up their outer layers late in life. Their blues, greens, and reds come from glowing gases such as hydrogen, helium, nitrogen, and oxygen.

Long before this was known, two 18th-century astronomers, Antoine Darquier de Pellepoix and William Herschel, both considered the shape of these nebulae planetlike. Herschel is widely credited with first calling them planetary nebulae, although there is no definitive answer as to whether the term truly originated with him.

Despite the name, only about 20 percent of planetary nebulae are spherical. The rest occur in a variety of shapes,



NGC 40

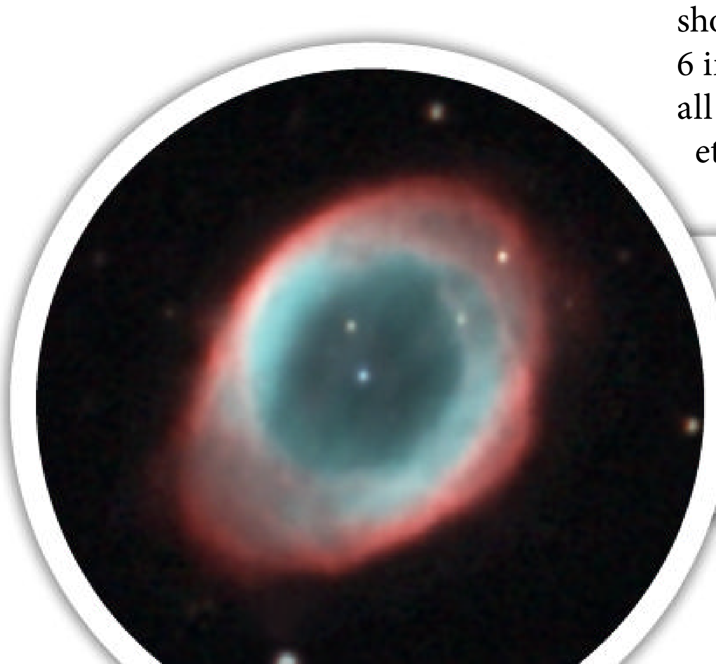
NGC 40 is a small but bright planetary nebula in Cepheus the King. Its glow is distinctly red — odd for this type of object. It sits in front of an unrelated supernova remnant, CTA 1. DOUGLAS J. STRUBLE

resulting from the particular way each central dying star sloughs off its outer layers. Their density ranges from 100 to 10,000 times that of empty interstellar space. The more colorful nebulae, which appear on this list, tend to have higher densities and appear round or oval in a telescope. That's because denser regions of gas glow more intensely.

Observing tips

The invention of the Oxygen-III (OIII) filter revolutionized observing planetary nebulae because the filter's peak transparency is the same wavelength as these objects' strongest emission. However, although a filter dramatically improves image contrast, it also blocks out natural color. To see their true color, it's best to observe planetaries without a filter. The full intensity of the unfiltered target will stimulate your cones, giving these compact nebulae color and even making them bright enough to spot from suburban skies. By contrast, faint and extended nebulae usually don't show color, and the special filters are designed for observing when the goal is simply finding the object, not revealing its color.

One common thread between the colorful planetaries on our list is their distance. Most are located between 1,000 and 5,000 light-years away. At these distances, they range from 15" to 40" in diameter — except for the Ring Nebula (M57), which is much larger. Bright planetaries can show color in telescopes as small as 6 inches. Larger apertures are better and all bear magnification well. A lot of planetaries have tenuous outer shells from previous eruptions, but these are too faint for most amateur telescopes. However, many on our list do reveal their central star — the white-hot engine lighting up these glowing balls from within.

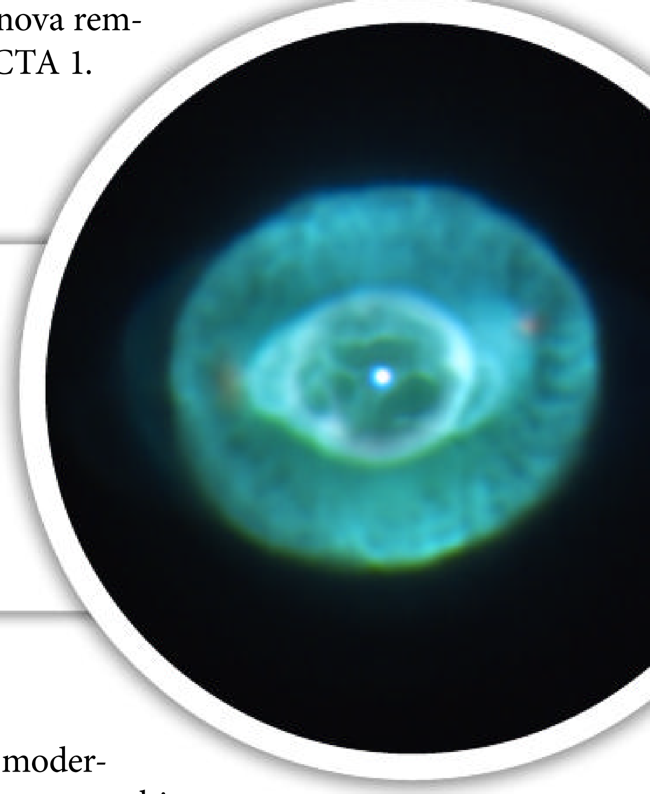


M57

One of just a few planetary nebulae in Charles Messier's catalog, the Ring Nebula (M57) looks just as its name indicates: a ring-shaped cloud in space, glowing green. MARK HANSON

The list

NGC 40 is the first target — and the most challenging. Located in the circumpolar northern skies at 72° declination in Cepheus, it's magnitude 10.4 and 35" across. It sits about 3,500 light-years distant. Some 1,000 light-years behind it is the unrelated, tenuous supernova remnant CTA 1.



NGC 3242

Also called the Ghost of Jupiter, NGC 3242 appears to the eye as a compact blue-green ball roughly the same angular size as Jupiter. Higher magnification will show it is slightly oblate. ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA

With moderate telescopes, this nebula resembles a partial ring that looks more like a parenthesis. It is also called the Bow Tie Nebula. The magnitude 11.4 progenitor star in the center is a rare Wolf-Rayet star — a type of star deficient in hydrogen and producing strong stellar winds. With a full magnitude of difference between the star and its nebula, some observers consider this one of the best targets in which to observe the progenitor. In large apertures (20 inches or more), NGC 40 shows a reddish hue, which is atypical for planetaries as normally, ionized oxygen and nitrogen give these objects green or blue colors.

NGC 6543

The author thinks of the Cat's Eye Nebula (NGC 6543) as the Atom Nebula because it contains intersecting rings that look like electron orbits in simple atom illustrations. ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA

NGC 2392 was once known as the Eskimo Nebula because it has a round interior surrounded by a ring of "fluffy" gas reminiscent of a head ensconced within a parka hood. However, after considering the term's derogatory history, NASA decided in 2020 to refer to the object only by its catalog name. It's recently also been described as the Lion Nebula, comparing the exterior gas to a lion's mane. Sources disagree on its exact distance: This dying star is located somewhere between 3,000 and 6,000 light-years away.

At magnitude 10.1, it's the brightest nebula in Gemini and an easy target with small telescopes. Seeing its bluish-green color requires more aperture rather than darker skies. Can you see it in an 8-inch scope?

NGC 6210

Tiny NGC 6210 hangs amid the stars of Hercules, showing off its stunning color. Challenge yourself to spot its 12th-mangitude central star. CHRIS SCHUR

NGC 3242 is sometimes called the Ghost of Jupiter for its shape and apparent size, reminiscent of our solar system's fifth planet. It's a colorful planetary tucked in Hydra, the largest constellation snaking its way through the spring skies. This nebula is 2° south and slightly west of Mu (μ) Hydrae. Binoculars or a finder scope will show it as a magnitude 8.6 star, while a small telescope reveals its nonstellar appearance. Under higher magnification, you'll see a slightly oblate disk 40" by 35" across. The nebula fluoresces greenish blue with a 6-inch scope and becomes bluer with increasing aperture.

The Ghost of Jupiter lies at least 1,400 light-years away and is about 2 light-years in diameter. The structure is a thin ring surrounded by a larger, tenuous envelope visible with larger telescopes. The central star shines at magnitude 11.7 and is visible in moderate apertures.

The **Ring Nebula** (M57) in Lyra glows at magnitude 8.8 and has an extended halo nearly 4' across. It was the first planetary nebula I ever observed. I was about 10 years old at the time, and my interest in stargazing was limited to locating Echo satellites. The telescope I used was a homemade 21-inch reflector owned by the Louisville Astronomical Society. Through it, M57 left an indelible memory because of its bright green color.

A decade later, that telescope, which included glass cast from the same formula as the 200-inch Hale telescope, was donated to the University of Louisville. When I observed M57 with that same telescope again at Moore Observatory, the green color was more muted. I've never seen it as bright green as in my childhood observation. It makes me wonder whether children see colors more intensely than adults. Or am I just remembering that vivid vista with green-tinted glasses?

NGC 6210 is the brightest planetary in Hercules and lies roughly 5,400 light-years away. Its location in our sky puts it more than 3,000 light-years above the Milky Way's disk, away from the bulk of its kin. It is a compact

NGC 6826

The Blinking Planetary Nebula (NGC 6826) does just as its name suggests: Switching between direct and averted vision makes it appear to blink in and out of your visual awareness. PETER GOODHEW

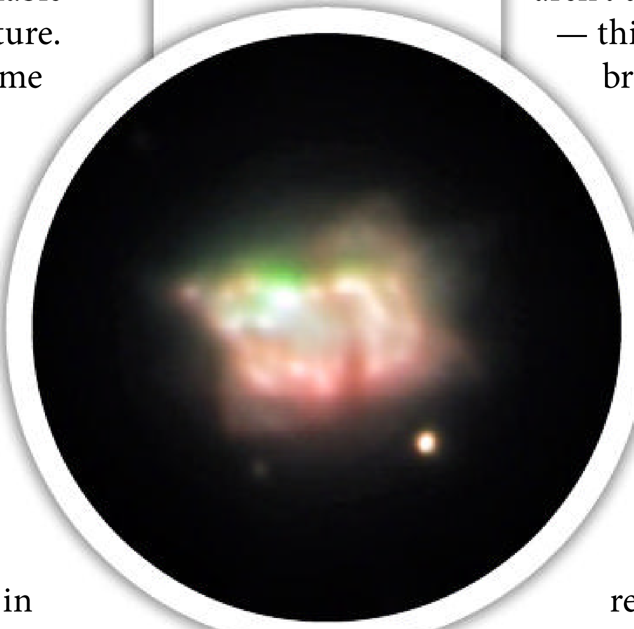
20" by 16" and magnitude 9.7. Its blue-green color is apparent in modest telescopes. Like most small planetaries, it bears magnification well, although spotting the magnitude 12.7 central star embedded within the bright nebula is a challenge.

The **Cat's Eye Nebula** (NGC 6543) in Draco is a compact 18" in diameter and shines at magnitude 8.8. I personally call this the Atom Nebula because it has two intersecting ellipses that remind me of electron orbits around the central star as the atom's nucleus. Its blue-green glow elongates in a north-south direction and is visible in a modest telescope. Even more detail within the nebula becomes available with increasing aperture. The central star is some 10 times hotter than the Sun and some observers claim it is easier to see with lower magnification. This dying star lies about 3,300 light-years away.

The famous **Blinking Planetary Nebula** (NGC 6826) in Cygnus offers a unique experience. The name comes from the odd optical effect you get when switching between normal and averted vision. When observing this object, I noted that while its green color was visible in the telescope, the central star appeared white when viewed straight-on. With averted vision, the nebula seemed to vanish — and the green color collapsed into the bright central star, giving it an intense verdant glow. A green star? That's what I saw! Try it.

The Blinking Planetary is a compact 27" by 24" and magnitude 9.8. The central star is about 0.5 magnitude fainter. It lies about 2,200 light-years distant.

NGC 7027 in Cygnus is a young nebula, both compact and dense at its distance of 3,000 light-years. Its 10th-magnitude, intense green glow is visible in small telescopes, but larger scopes show its 15"-wide boxy shape better. The central star is deeply embedded in the gas cloud and beyond viewing for the most part. This is a great object to observe with your high-power eyepieces.



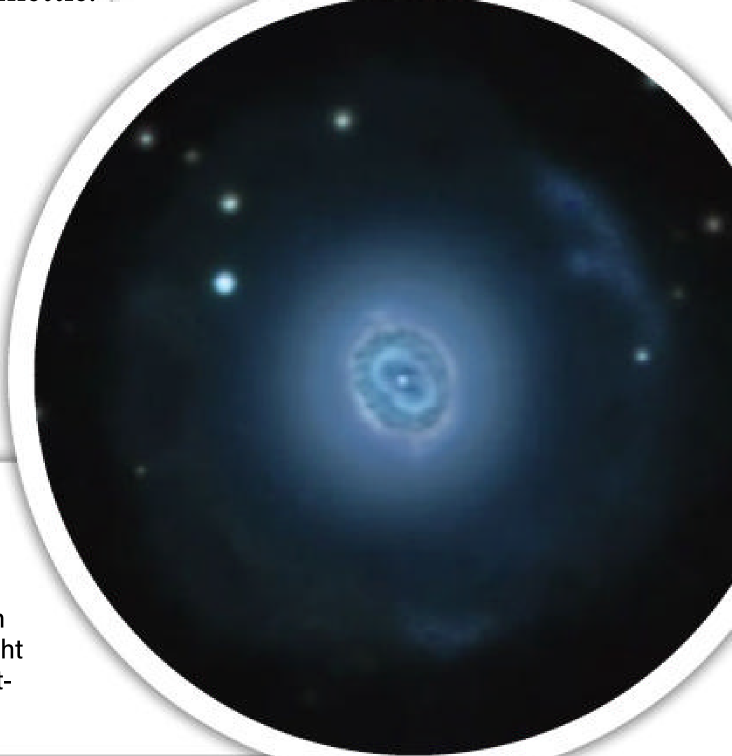
NGC 7027
NGC 7027 shows its boxy shape in larger telescopes. Its dense concentration of gas and dust hide the central star from view. ADAM BLOCK/NOAO/AURA/NSF

The **Saturn Nebula** (NGC 7009) is easy to find, lying about a degree west of Nu (ν) Aquarii. It is a bright magnitude 8.3, 41" by 35" across, and shows green or yellow color in small telescopes. Its Saturn-like "rings" are formed by structures called ansae: symmetrical knots of gas at each end of the nebula's long axis. And they aren't unique to NGC 7009 — this object is simply the brightest example you'll see through your telescope. When Herschel discovered it in 1782, the nebula's shape stumped him. He couldn't figure out how it had formed. (Today, researchers believe ansae are related to a star's behavior as it ages into a planetary nebula.) The Irish observer William Parsons, Earl of Rosse, later coined the name. It lies between 2,000 and 4,000 light-years away.

NGC 7009
The Saturn Nebula (NGC 7009) features bright ansae, or handles, at the ends of its Saturn-like rings. Upon finding this object in 1782, William Herschel couldn't explain how it had formed. DANIEL VERSCHATSE

NGC 7662 is Andromeda's brightest planetary nebula and sports a simple and visually accurate moniker: the Blue Snowball. At 2,200 light-years away, it is an easy magnitude 8.3 and spans 32" by 28". One of my most memorable observations of this object was with a 12-inch Alvan Clark reflector at the University of Louisville's on-campus observatory. Viewed from atop the four-story Natural Sciences building in an urban area, the Blue Snowball lived up to its name, proving that deep-sky observing can be done even with light pollution present. The high contrast of compact planetaries makes them ideal targets for mediocre skies.

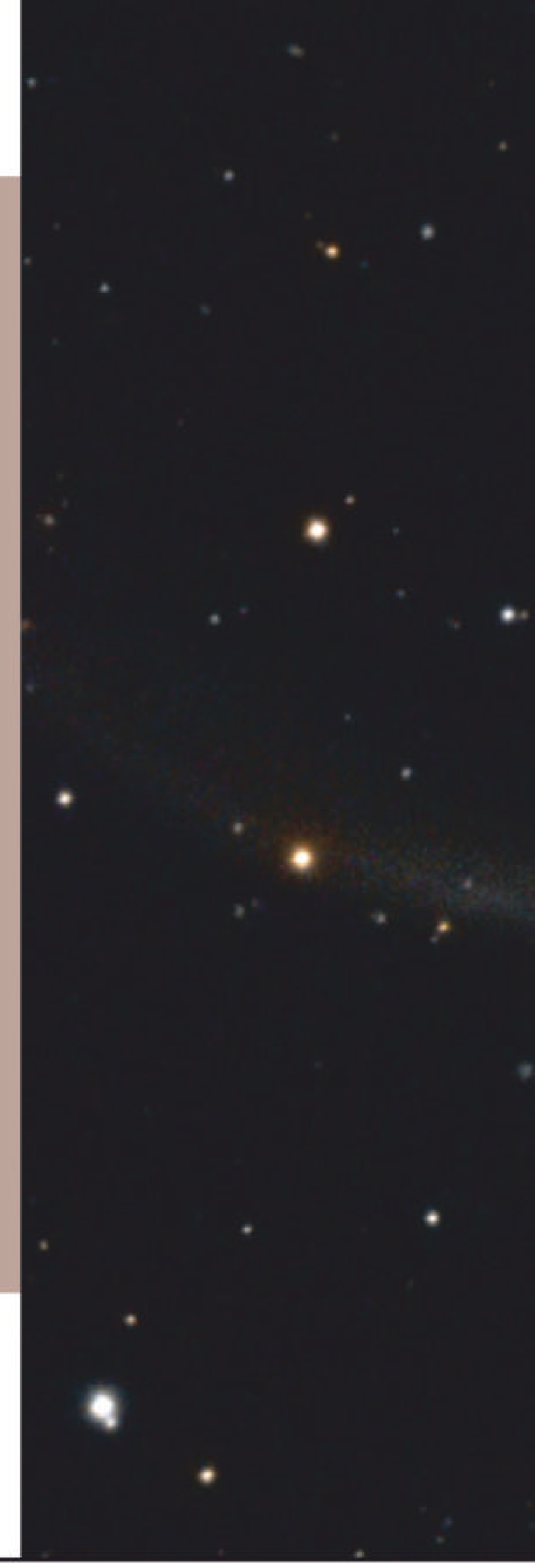
Of course, there are plenty of other planetary nebulae that show color. This list is just the beginning. Whether you use a large or small telescope, this group of deep-sky objects offers a broad spectrum of challenges. From discerning color, detail, and the central star to simply separating the distant, tiny nebula itself from the rich background of Milky Way, these colorful and compelling targets present opportunities to test any stargazer's mettle.



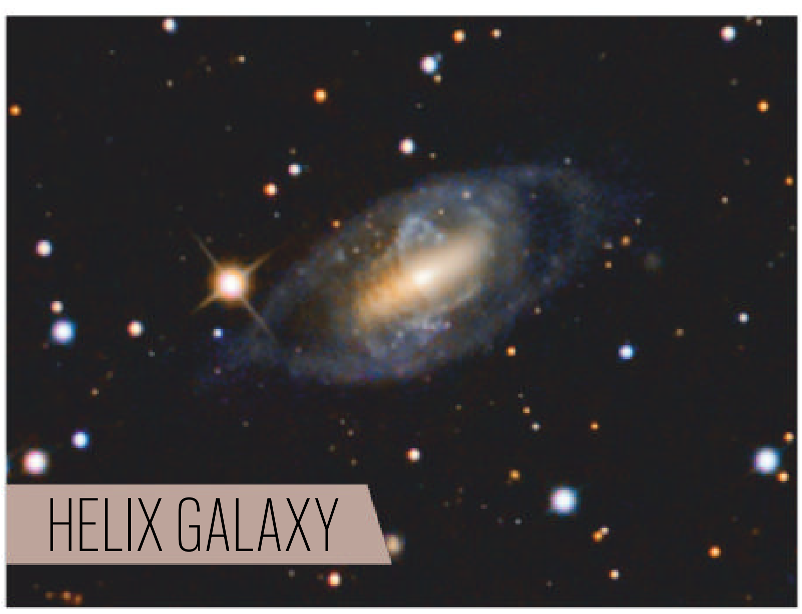
NGC 7662
NGC 7662 is also called the Blue Snowball — and that's exactly what you'll see through your scope. This relatively bright target is good even under light-polluted skies. DEREK SANTIAGO

Alan Goldstein *has observed planetary nebulae since the mid-1970s. They are his favorite deep-sky object — after galaxies.*

Beyond the Messier marathon



If you're tired of running the same old race, here's a new route through the night sky. BY MICHAEL E. BAKICH



The Helix Galaxy (NGC 2685) is a polar ring galaxy — a rare formation thought to be caused by two galaxies colliding. DON GOLDMAN

THIS YEAR, there are two windows to run a Messier marathon: a few days around New Moon (March 2), and from sunset until the Moon rises around Last Quarter (March 24) through New Moon (April 1). But if you've done the Messier marathon once — or multiple times, as I have — you might enjoy a different list of deep-sky treats to track down instead when the Moon isn't in the evening sky.

My alternate list has objects for telescopes of all sizes. Objects are ordered by their right ascension, so the ones at the beginning rise around sunset in early March and are highest around midnight, or 1 A.M. when daylight saving time takes effect March 13.

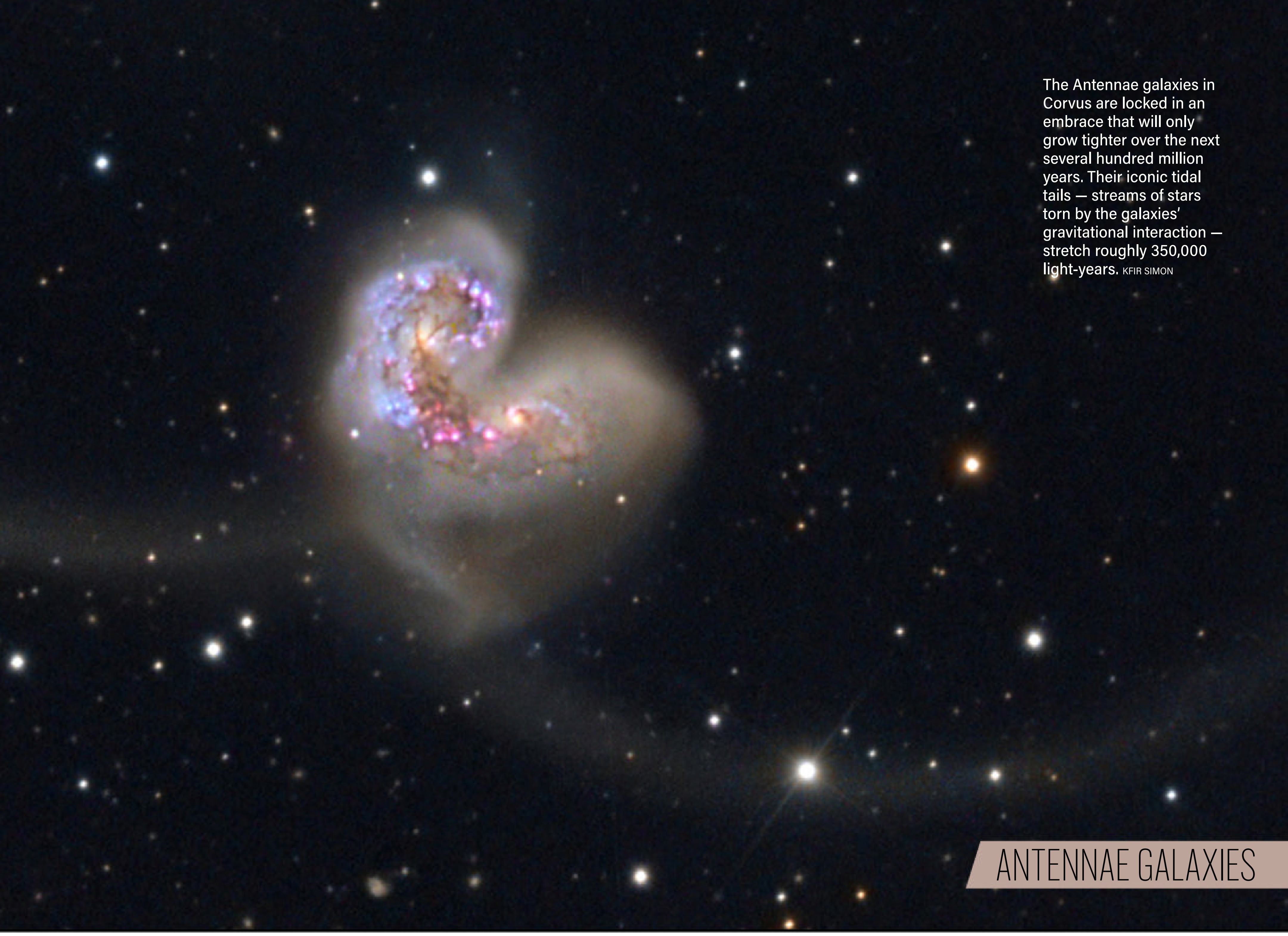
The descriptions are short because of limited space, but that doesn't mean you should just take a quick glance and move on. Get comfortable, spend some quality time with each object, and you'll have at least as much fun as your friends who are stuck trying to figure out which M object they're staring at in the Virgo Cluster.

Start the non-marathon

The first object is the **Helix Galaxy** (NGC 2685), a magnitude 12.7 spiral in Ursa Major. You'll find it 3.8° east-southeast of Muscida (Omicron [o] Ursae Majoris). At low magnifications, you'll see a disk-shaped glow twice as long as it is wide (4.9' by 2.4'). To see the ephemeral ring that gives the galaxy its common name, you'll need a 14-inch scope.

Next up is **NGC 2768**, also in Ursa Major. It glows at magnitude 9.9 and measures 6.4' by 3.0'. Some references classify this galaxy as elliptical, but it's lenticular, with a clear disk. NGC 2768's core and outer halo are evenly illuminated.

Now head to Cancer and **NGC 2775**. This is a magnitude 10.1 spiral with dimensions of 4.6' by 3.7'. Through an 8-inch scope,



The Antennae galaxies in Corvus are locked in an embrace that will only grow tighter over the next several hundred million years. Their iconic tidal tails — streams of stars torn by the galaxies' gravitational interaction — stretch roughly 350,000 light-years. KFIR SIMON

it looks oval. A 12-inch scope at 250x reveals the outer halo.

Our next target, the magnitude 10 spiral **NGC 2784** in Hydra, lies 1.9° north-northeast of Kappa (κ) Pyxidis. Through an 8-inch scope, you'll see a stretched core surrounded by a similarly shaped halo. It measures 5.5' by 2.4'.

No. 5 on this list, **NGC 2787** in Ursa Major, is a bit of an odd duck. Astronomers classify it as a barred lenticular galaxy. It glows at magnitude 10.9 and measures 3.1' by 1.8'. Through a 12-inch or larger scope, you'll see the bar, but its long axis tilts a bit relative to the long axis of NGC 2787.

Next up is gorgeous **NGC 2841**, a magnitude 9.3 spiral in Ursa Major. Look for it 1.8° west-southwest of Theta (θ) Ursae Majoris. It measures 8.1' by 3.5'. Through an 8-inch scope, you'll see several dark regions in its spiral arms, but the arms themselves are tough to see.

Leo contains many fine galaxies, five of which made Messier's list. Don't overlook **NGC 2903**, however, which shines brighter (magnitude 9.0) than any of that quintet save M66. It measures a worthy 12.0' by 5.6'. Through a 10-inch scope, look for a halo that surrounds a bright core. Be patient and look closer for the central bar and the spiral arms. Larger scopes show dust lanes and emission nebulae throughout NGC 2903's arms.

Next up is irregular galaxy **Sextans B**. To find this object, aim 6° north-northwest of magnitude 4.5 Alpha (α) Sextantis. Through a 12-inch scope, you'll see a magnitude 11.3 rectangular (5.5' by 3.7') smudge of light dotted by faint foreground stars. Can you tell that the central region is ever-so-slightly brighter?

Look for the next target, magnitude 10.9 barred spiral **NGC 3079**, 2.2° northeast of Phi (φ) Ursae Majoris. I love

Instead of the clear structure of a grand design spiral galaxy, the arms of NGC 2775 are feathery and patchwork, giving it its classification as a flocculent spiral galaxy. ADAM BLOCK/MOUNT LEMMON SKY CENTER/UNIVERSITY OF ARIZONA

CLOCKWISE FROM TOP: NGC 2903 is one of the brightest deep-sky objects in the northern sky that escaped Messier's attention when he compiled his catalog. RAY J. GABANY

NGC 4435 and NGC 4438 (The Eyes) are roughly 54 million light-years away and part of the larger formation of galaxies called Markarian's Chain. DAN CROWSON

The Leo Galaxy Cluster (Abell 1367) has at least 70 galaxies — many of them spirals, indicating that the cluster is relatively young and still forming stars. DAVE DOCTOR

observing galactic "splinters," and NGC 3079 appears more than five times as long as it is wide (8.0' by 1.5'). Through a 12-inch scope at 300x, the bright center stretches two-thirds of the galaxy's length.

Not only is the **Spindle Galaxy** (NGC 3115) the showpiece of Sextans, at magnitude 8.9 it's one of the sky's brightest galaxies. Through a 4-inch telescope, you'll see an object four times as long as it is wide (8.1' by 2.8') with a bright center. Through a 12-inch scope at 300x, the core looks more distinct, surrounded by an oval bulge.

Our next target is dwarf spheroidal galaxy **Leo I**. It's easy to find, only 20' due north of Regulus (Alpha Leonis). But that brilliant star's glare through the eyepiece makes Leo I difficult to see, so keep Regulus outside the field of view. At a dark site, an 8-inch telescope at 150x reveals a uniform, magnitude 10.2 mist measuring 12.0' by 9.3'.

Follow Leo I with the **Little Pinwheel Galaxy** (NGC 3184) in Ursa Major. It glows at magnitude 9.8 and measures 7.8' by 7.2'. This is a gorgeous galaxy through a large scope. NGC 3184 has wide arms, so use high power — above 400x — to spot the dark regions that divide them from the nucleus.

Next up is the spring sky's showpiece planetary nebula, the **Ghost of Jupiter** (NGC 3242) in Hydra. With a magnitude of 7.8, it's bright. At low power through a 6-inch scope, you'll see the 16"-wide, blue-green disk. Through larger scopes, and at powers in excess of 200x, the center looks like an eye surrounded by a faint spherical shell 40" across. For best results, use a nebula filter.

Although our next object is called **Coddington's Nebula** (IC 2574), it's a magnitude 10.4 spiral galaxy in Ursa Major. Look for it 5.7° west of Lambda (λ) Draconis. Through an 8-inch scope at 75x, it appears twice as long as it is wide (13.5' by 8.3'). The central region glows a bit brighter and looks offset to the southwest.

Although you'll need to head to Leo Minor for the **Sliced Onion Galaxy** (NGC 3344), the best way to find it is to look 6.3° east-northeast of Zeta (ζ) Leonis. This spiral glows at magnitude 9.9 and measures 6.9' by 6.4'. An 8-inch scope shows a bright core. Double the aperture and NGC 3344's many arms wind tightly around the core, making the galaxy appear circular.

Our next target is spiral galaxy **NGC 3521** in Leo. Because it lies just 28 million light-years away, it appears big (12.5' by 6.5') and bright (magnitude 9.0). NGC 3521 sits in a small region of Leo between Sextans and Virgo 4.5° northwest of Phi Leonis. Through a 10-inch telescope, you'll see the bright, extended core surrounded by a diffuse halo. With a 16-inch scope, NGC 3521 will look nearly twice as long as it does through the smaller instrument.

Drop south to Hydra for the **Frame Galaxy** (NGC 3621), a magnitude 8.9 spiral that lies 3.3° west-southwest of Xi (ξ) Hydrae. This object is twice as long as it is wide (9.8' by 4.6') with a broad, evenly lit core. The halo, however, reveals mottling, which suggests spiral structure. NGC 3621's common name comes from a parallelogram of stars that surrounds it, making the galaxy appear framed.

Can you access a large scope? You'll need one for the **Leo Galaxy Cluster** (Abell 1367). This cluster

spans 1.6° mainly to the southwest of the star 93 Leonis. At 330 million light-years away, the galaxies' light appears faint, but a 10-inch or larger scope will wrangle a couple dozen members. For example, the centrally placed, nearly 1'-wide glow of magnitude 11.8 NGC 3842 shows up nicely through an 8-inch telescope at a dark site. Others you'll be able to spot include magnitude 12.7 NGC 3861, magnitude 12.7 NGC 3862, magnitude 13.3 NGC 3837, and magnitude 13.7 NGC 3840. To guarantee success, a good finder chart of this cluster is a must.

Next up is a pair of interacting galaxies in Corvus that astronomers refer to as the **Antennae Galaxies** because of their bright tails. The two are NGC 4038 and its companion NGC 4039. They have a combined magnitude of 10.5 and span 5.4' by 3.9'. To find them, look 3.6° west-southwest of Gienah (Gamma [γ] Corvi). A 4-inch telescope at a dark site will reveal two faint, cottony smudges. The larger and brighter smudge, NGC 4038, sits to the northwest. A 12-inch scope at 200x shows both oval cores roughly twice as long as they are wide. If the seeing is good, double the power and you'll see bright and dark knots and traces of at least one tidal tail.

Now point your scope 1.5° west of magnitude 3.9 Kappa Draconis. There you'll find the magnitude 9.6 barred spiral **NGC 4236**. While that magnitude may seem bright, this galaxy is so huge (21.0' by 7.5') that its surface brightness is low, so you might not see it through anything smaller than a 10-inch scope. That aperture reveals a ghostly mist three times as long as it is wide. Larger scopes reveal a few faint star-forming regions. The brightest lies at the south end of the spindle.

Have I mentioned Canes Venatici yet? Although its stars are faint, it contains many bright galaxies. Four made Messier's list — M51, M63, M94, and M106. And although the **Silver Needle Galaxy** (NGC 4244) isn't as bright as those luminaries, it's well worth a look. It glows at magnitude 10.4 and measures 17.0' by 2.2'. Its disk is edge-on, tilting only 5° to our line of sight. Its length is relatively evenly illuminated, with a slightly brighter core. View NGC 4244 through a 4-inch scope from a dark site, and you'll understand why its name contains the word *needle*.

Next up is another galactic pair called **The Eyes** (NGC 4435 and NGC 4438), which lie in Virgo. Together, they glow at magnitude 10.0 and measure 8.5' by 3'. Although you'll spot this duo through small scopes, it will take at least a 12-inch telescope to coax out any details. To find The Eyes, look 8.5° west of Vindemiatrix (Epsilon [ε] Virginis). You'll most likely first spot M86. Your target is 0.4° east of that galaxy. NGC 4438 is the more distorted galaxy of the two. Crank up the power and try to spot this object's irregular outer regions.

I think you'll like our next object, the irregular galaxy **NGC 4449**. Look for it 2.9° north-northwest of Chara (Beta [β] Canum Venaticorum). It glows at a worthy magnitude 9.6, but it's the high surface brightness that makes this target easy to observe. Through an 8-inch telescope, you'll see NGC 4449's unusual rectangular shape (5.5' by 4.1'). It has a bright nucleus that also looks rectangular. Crank the magnification past 250x and examine the irregular halo outside this galaxy's core.

Stay in Canes Venatici for the **Cocoon Galaxy** (NGC 4490), a magnitude 9.8 barred spiral that measures 6.4' by 3.3'. It lies 0.7° west-northwest of Chara. Through an 8-inch scope, you'll see an irregularly bright oval halo (the "cocoon") surrounding a bright core. If your sky is steady, look 3' north of NGC 4490's western end for its magnitude 12.5 companion, irregular galaxy NGC 4485.

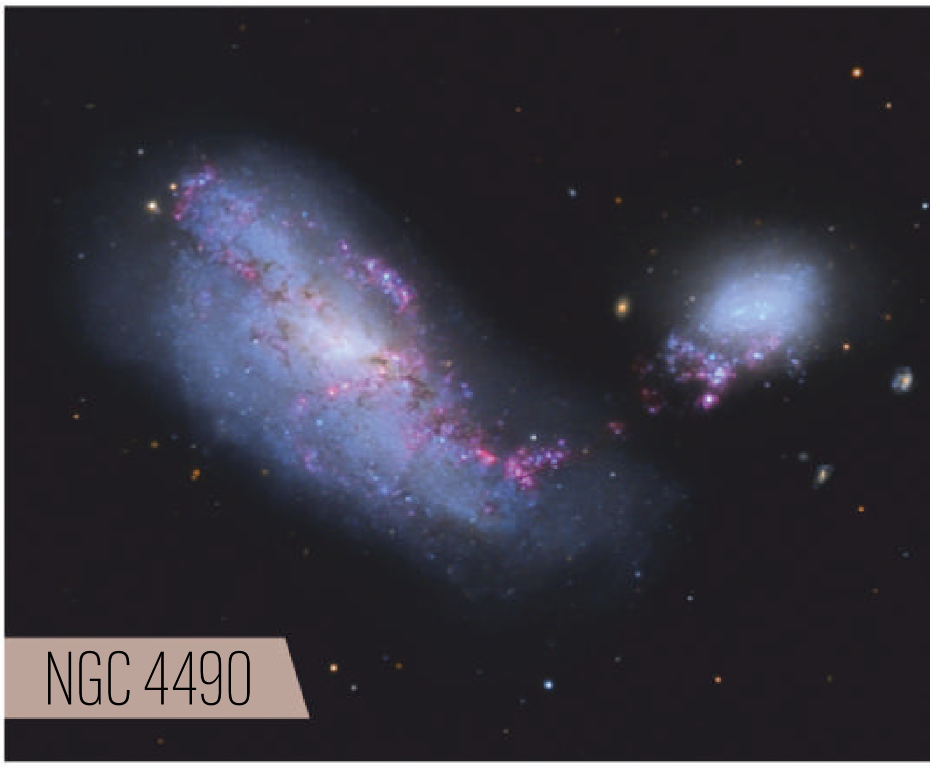
I'll end this list with a great target: the **Needle Galaxy** (NGC 4565) in Coma Berenices. In my opinion, this is the sky's finest edge-on spiral. It glows at magnitude 9.6 and measures 14.0' by 1.8'. An 8-inch scope shows a streak roughly 10' by 1.5' oriented northwest to southeast. A dust lane runs the length of this object, and the small bulge of the core is the easiest place to spot it.

It's OK to observe the objects on Messier's list many times. As this brief list proves, however, there are many other worthy targets that await your viewing pleasure. Good luck!

Michael E. Bakich *is a contributing editor of* Astronomy *who no longer observes Messier objects in March.*

BELOW LEFT: The edge-on spiral Needle Galaxy (NGC 4565) may look as straight as its namesake, but it is in fact slightly warped, probably from interactions with other galaxies. SERGEY TRUDOLYUBOV

BELOW RIGHT: The Cocoon Galaxy (NGC 4490) is seen here with its irregular companion, NGC 4485. In 2020, astronomers reported that the Cocoon Galaxy has a double nucleus. One nucleus can be seen in visible light and one is seen only in infrared and radio wavelengths. ADAM BLOCK/MOUNT LEMMON SKY CENTER/UNIVERSITY OF ARIZONA

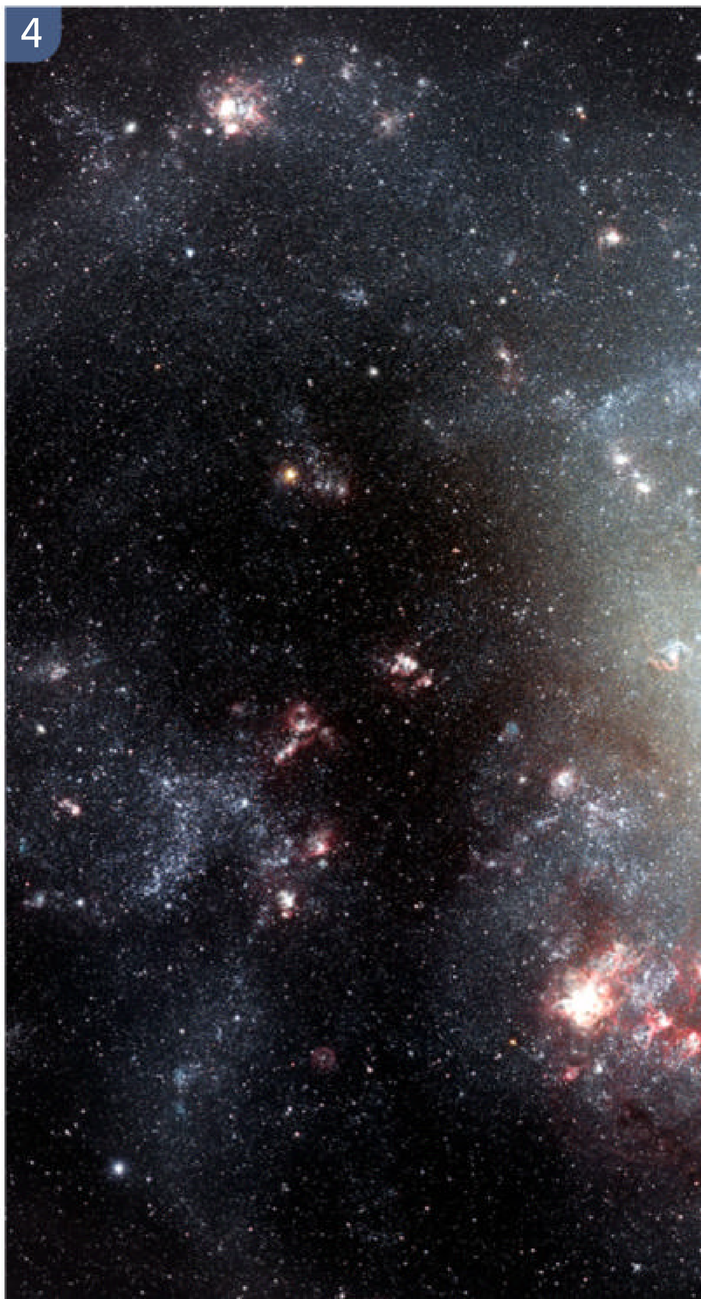


1 The Large Magellanic Cloud — seen here hanging over the Atacama Desert — is unmissable in the southern sky. G. HÜDEPOHL (ATACAMAPHOTO.COM)/ESO

2 NGC 1760/63/69/73 comprise the second most prominent nebula complex in the Large Magellanic Cloud, after the Tarantula Nebula (NGC 2070). ALAN DYER

3 NGC 1850 is a young super star cluster containing the mass of roughly 42,000 Suns. NGC 1850A is just west (right) of the main cluster. STEVEN JUCHNOWSKI

4 The Large Magellanic Cloud is one of the Milky Way's closest satellite galaxies, with a mass roughly 10 billion times the Sun. It likely had a barred spiral structure before its arms were distorted by gravitational interactions with the Milky Way and the Small Magellanic Cloud. FERNANDO OLIVEIRA DE MENEZES



Leap into the Large Magellanic Cloud

The Milky Way's close companion is more than just a single deep-sky object — it's a bustling galactic metropolis waiting to be explored.

BY MICHAEL E. BAKICH

THE LARGE MAGELLANIC CLOUD (LMC) is the southern sky's greatest celestial wonder. It is the Milky Way's biggest satellite galaxy, just 160,000 light-years distant, and the fourth-largest member of the Local Group. The LMC lies primarily in the far-southern constellation Dorado the Swordfish, but some of it spills over into the neighboring constellation Mensa the Table Mountain, which lies even farther south. To see even part of the LMC, you must be south of latitude 20° north. And for it to appear even halfway up in the sky at its highest, you'll need to be at latitude 25° south.

With a magnitude of 0.4, the LMC is an easy naked-eye object even from mildly light-polluted areas, so let's start by looking at it as a whole. Under a dark sky, use just your eyes to look at the LMC. You'll see that its brightest region is a bar roughly 5° long by 1° wide. That makes it 10 times as long and twice as wide as the Full Moon. The surrounding region is a fainter, oval haze measuring an amazing 6° by 4°. And you can extend the LMC's boundary beyond this — just use binoculars or a low-power rich-field telescope.

Through a 6-inch or larger scope and an eyepiece that gives a magnification around 200x, slowly scan back and forth across the LMC's face. You'll see lots of star clusters and nebulae in the field of view. If you screw a nebula filter (perhaps an Oxygen-III) into your eyepiece, it will help you distinguish the nebulae from the clusters. The filter won't make the nebulae brighter; rather, it will block most of the light from stars so the clusters won't be as apparent.

Deep-sky objects abound in the LMC. It contains no less than 114 NGC objects. Here are a few that I've enjoyed looking at each time I've had the chance.

Crank up the power

Let's start this list with **NGC 1714**. This tiny emission nebula (it measures only 1.2' across) sits on the western edge of the LMC just over

6° southwest of magnitude 3.8 Beta (β) Doradus. Although it is small, its high surface brightness lets you crank up the magnification for a detailed view. Through an 8-inch scope, you'll see a round glow with a bright northern rim. A magnitude 6.3 star, GSC 8889:215, lies just 8" west. And as a bonus, slightly fainter **NGC 1715** — another emission nebula — lies 1' north of NGC 1714.

Our next target, open cluster **NGC 1755**, also lies on the western edge of the LMC's bar, slightly south of NGC 1714. It glows at magnitude 9.9 and is 2.6' across. An 8-inch telescope at 100x reveals 20 stars of magnitudes 13 and 14 packed into an area 2' wide. You'll also see a strong background glow from lots of stars too faint for your scope to resolve. A much fainter open cluster, NGC 1749, which glows at magnitude 13.5, lies 2' to the northwest. You'll need a lot more than 8 inches of aperture to spot it.

Our next target — or should I say group of targets, four emission nebulae — lies about 2° north of NGC 1755. They're close together, too, in an area less than 0.3° across. The one you'll notice first is **NGC 1763**. It appears as a clumpy haze that measures 5' by 3', surrounded by a grouping of stars that looks like an open cluster — but it's not. Just 7' south, you'll find **NGC 1760**. Move 7' east-southeast from NGC 1763, and you'll encounter **NGC 1769**. Finally, **NGC 1773** lies 9' east-northeast of NGC 1763.

Because the LMC is a galaxy, we expect it to contain the full range of deep-sky objects. (OK, except for galaxies.) Seek out **NGC 1835**, also along the western part of the bar, and you'll be looking at a globular cluster, one of only two on this list. It glows at magnitude 10.1 and measures 1.2' across.

NGC 1835 looks round at low power, but crank up the magnification and you'll see faint extensions to the east and west that double its length. Two faint open clusters, magnitude 12.5 NGC 1828 and magnitude 12.6 NGC 1830, lie 6' to the northwest.

Next up is the massive open cluster **NGC 1850**. In fact, astronomers classify this as a super star cluster, one that is brighter and more massive than normal open clusters, which also may eventually become a globular cluster. You'll find NGC 1850 in the northeastern part of the LMC's bar, with an apparent diameter of 3.4'. It's so bright that it glows at magnitude 9.0.

5

Point an 8-inch scope at this cluster, and you'll see roughly 50 stars glowing at magnitudes 13 and 14. The prominent clump of stars on NGC 1850's western edge, NGC 1850A, actually makes this object a double cluster.

Our next object, **NGC 1866**, is another open cluster that lies in the northern reaches of the LMC. I think this object will amaze you through a 12-inch or larger telescope. It glows at magnitude 9.7 and spans 4.5'.

The easiest way to find it is to start at Beta Doradus and sweep 3.7° south-southwest. The brightest stars in this cluster glow at 15th magnitude, so you'll need a large aperture to reveal them. Through a 14-inch scope with an eyepiece that yields a magnification of 300x or higher, you'll see hundreds of stars.

The most remarkable star-forming region anywhere is R136.

Moving to the north central region of the LMC, you'll come across yet another clump of four emission nebulae, but they're packed even closer together than the previous group I described. Indeed, **NGC 1962**, **NGC 1965**, **NGC 1966**, and **NGC 1970** fit into a region only 5' across.

Through an 8-inch telescope at low power, NGC 1962 will be the most apparent, although even it appears circular and featureless. Then crank up the magnification above 200x and examine the region north and east of NGC 1962. You'll see the other three nebulae arcing along its rim.

Our next target is the other globular on this list, **NGC 2019**. It lies along the LMC's bar just to the east of its center. It's not bright, glowing at magnitude 10.9. It's also pretty small, measuring a scant 1' in diameter. The reason you'll see it, however, is because of its small, bright central region. NGC 2019 has a collapsed core — meaning its stars are unusually concentrated at its center — a phenomenon that's happened in several other globular clusters in the Magellanic Clouds.

An 8-inch telescope will reveal the core easily. It actually appears lumpy

5 The massive Tarantula Nebula contains the most intense star formation in the entire Local Group. For more on the Tarantula, see "Untangling the Tarantula Nebula" in the September 2021 issue. FERNANDO OLIVEIRA DE MENEZES

6 The open cluster NGC 2100 lies on the outskirts of the Tarantula, surrounded by tenuous wisps of gas set aglow by the energy of the nebula's young, blazing stars. RAY J. GABANY

rather than starlike. Crank the power past 200x, and you should be able to spot NGC 2019's irregular outer boundary. If you can double your aperture to 16 inches, individual stars will appear.

Our next object — the **Tarantula Nebula** — is the standout on this list and the only one with a common name. It has two others: 30 Doradus and the True Lover's Knot. It's also often called NGC 2070, but that specifically refers to the super star cluster at the nebula's center.

Because it lies so far south, most northern observers haven't experienced this celestial wonder. And although it is some 160,000 light-years away, the Tarantula Nebula looks incredible even through medium-sized telescopes. Although its apparent diameter is 40' by 25', its true diameter is slightly more than 1,800 light-years. If it were as close as the Orion Nebula (M42), it would span over 60° — one-third of the entire sky.

The brightest star cluster in the Tarantula Nebula and the most remarkable star-forming region anywhere is R136, whose designation comes from the *Radcliffe Observatory Magellanic Clouds Catalogue*, published in 1960. This cluster alone glows at magnitude 9.5. The 75 spectral class O stars at its heart are among the most massive, brightest, and hottest known. Its total mass is more than 450,000 times that of the Sun. This cluster produces the ultraviolet radiation that causes the Tarantula Nebula to shine.

Observers with even a 4-inch telescope will see a dense bar running north to south through the nebula's center. Then look for the loops and filaments within the gas. The longest filament begins near the cluster's center and extends 7' to the south. It then heads eastward and curves an equal distance to the north. R136 is easy to spot as a 1'-wide region, and if you crank up the magnification, you'll be able to pick out several dozen of its bright stars.

Look also for the two dark bays, one slightly darker than the other, just east of R136. Both these regions have nebulous filaments encroaching on their borders. Their appearance led English astronomer William Henry Smyth to describe this nebula as the True Lover's Knot. Some accounts say that 16th-century Dutch sailors tied similar knots to remind them of lovers they'd left behind.

Once you have found the Tarantula Nebula, head just 0.3° east to open cluster **NGC 2100**. It glows at magnitude 9.6 and measures 2.8' across. If you use an 8-inch telescope and a magnification around 200x, the first feature you'll see will be the compact core. You'll need higher power (and probably a bigger scope) to resolve any of its stars. Just surrounding the core, however, you should see about two dozen stars.

The final object on this tour is open cluster **NGC 2214**. It has a diameter of 3.6' and a magnitude of 10.9. You'll find it 4.5° east-northeast of the LMC's center. For a better marker, look 0.7° north-northeast of magnitude 5.1 Nu (ν) Doradus.

A 4-inch telescope will show NGC 2214 as a faint haze. This is a tough nut to crack, though, even through a 12-inch scope. Crank the magnification to 250x or beyond and you'll just start to resolve some of the cluster's stars at its edge.

Observe at your own pace

When you train a telescope on the Large Magellanic Cloud, don't rush to see everything. Many of the objects I've just described — the Tarantula Nebula being the exception — take a bit of coaxing at the eyepiece. Believe me, your patience will be rewarded.

Michael E. Bakich *is a contributing editor of* Astronomy *who is always ready to travel south of the equator to observe.*

VIXEN

ADD THE Polarie U TO YOUR TOOLBOX

Vixen's star tracker will suit your observing needs, no matter your experience level.

BY RAYMOND SHUBINSKI

HAVE YOU EVER stepped back from your telescope, looked around you, and felt the urge to capture the beautiful landscape and a star-studded sky in the same image? Go online and you'll find a deluge of opinions on the best camera to take such images. However, behind almost every shot is not just a great camera, but a good tracking device.

Star trackers allow you to take longer exposures, making those diamonds in the night sky pop. For 50-odd years, I have done tripod-mounted astrophotography, collecting images of every constellation visible from latitude 35 degrees. But the craving to capture wide-field vistas with a blanket of stars above finally struck. I began my search for a simple-to-use, high-quality star tracker. The Vixen Polarie U Star Tracker fit the bill.

Tech and specs

Vixen Co. of Japan, founded in 1949, is well known for not only its outstanding telescopes, but its eyepieces, binoculars, and sturdy mounts. They have long provided equipment for astrophotography, and now offer a star tracker that gives outstanding support for widefield images of the night sky.

When I received a small box from Vixen containing the Polarie U tracker, I was surprised at the compact size of the unit. At just 1.26 pounds (0.57 kilograms) and a mere 3.5 by 2.8 by 4.4 inches (8.9 by 7.2 by 11 centimeters), it fits comfortably into the palm of most people's hands. Also included in the box was a polar alignment scope and mounting bracket.

Getting started with the unit is straightforward. I used a Celestron alt-azimuth mount for added stability. The Polarie U has a detachable mounting block on the front. I removed this to attach a ball-head camera mount. (This is not included with the Polarie U, but Vixen does have one available for separate purchase.) Then I just slipped a camera onto the ball head.

The maximum loading weight for the base Polarie U is 5.5 pounds (2.5 kg). But

if you purchase and combine the Polarie Multi mounting block and Dovetail Slide Bar DD, you can reach a capacity of 14 pounds (6.5 kg).

On the top of the device is a band with a mode indicator. Below the indicator is an on/off switch and two buttons. The power switch has positions for two modes of operation, marked N and S, which allows you to choose whether you are in the Northern or Southern Hemisphere.

Once the unit is turned on, the indicator band lights up with five tracking options. The first is the half-speed tracking rate used for starscape photos. This mode splits the difference between the moving star field and the stationary landscape, allowing you to maximize your exposure time before blurring of either element becomes apparent. Next is a star icon, which provides full-speed celestial tracking for taking photos of star fields with no landscape. The next two icons are for solar and lunar tracking.

There is also a button with a phone icon. This feature activates the built-in Wi-Fi, which lets you link a phone or tablet to the Polarie U. Vixen has developed their own app that is available for iOS and Android. The app allows you easy access to speed controls, custom modes, bracketing options, and a lot more. One nice feature is being able to remotely control the camera shutter from the app.

Power for the Polarie U comes from four AA batteries or an external power supply connected via USB-C. Vixen says four new AAs will last seven hours at 68 degrees Fahrenheit (20 degrees Celsius).

To track the passage of stars in the Northern Hemisphere, the Polarie U must be aligned to Polaris, the north star. (For the Southern Hemisphere, using three stars in constellation Octans will do the trick.) The basic Polarie U comes with a simple sighting tube which slides onto the camera shoe on top of the unit. This only provides a rough polar alignment, however. Vixen also sells a polar alignment scope that attaches to the tracker with a bracket. If you plan to do more than basic starscape images, this would be worth adding to your equipment.

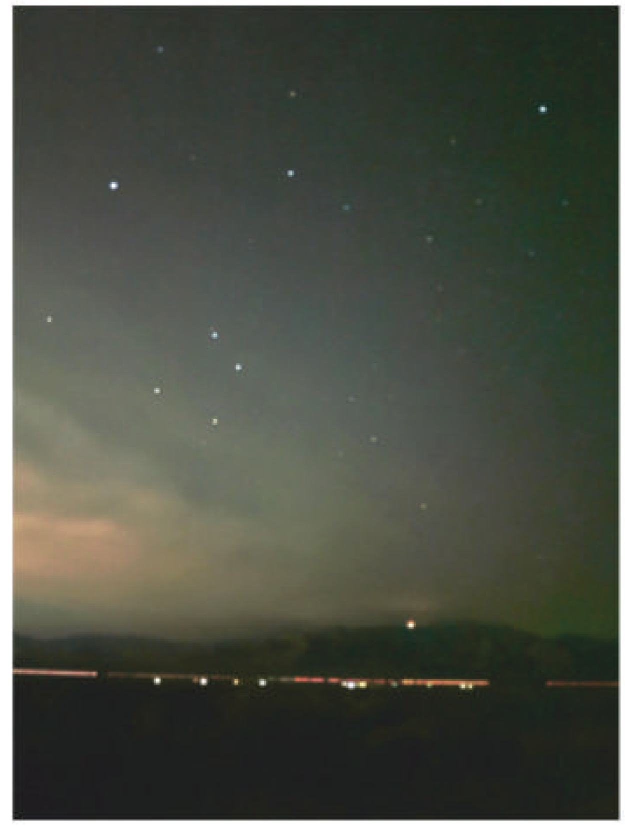
Instructions included

To test the unit, I set up a Nikon D610 digital camera on the Polarie U to take a few photos under a partly cloudy sky.

PRODUCT INFORMATION

Vixen's Polarie U Star Tracker

Tracking rates: Celestial speed, 0.5x celestial, solar, lunar
Maximum load: 5.5 pounds (2.5 kilograms)
Power: Four AA batteries, Ni-MH or Ni-Cd rechargeable batteries, or USB Type-C external power batteries
Battery life: About 7 hours at 68 degrees Fahrenheit (20 degrees C)
Dimensions: 88.5mm x 72mm x 110.5mm
Weight: 1.26 pounds (0.57 kilograms)
Price: Not available yet
Contact: Explore Scientific (U.S. distributor)
1010 S. 48th Street
Springdale, Arizona 72762
866.252.3811



RAYMOND SHUBINSKI

Some of my first shots with the Polarie U: While not my best work, this star tracker has made me excited to try some more sky photos.

RAYMOND SHUBINSKI

Taking good star photos depends on a number of factors. One of the most crucial ingredients is the skill and experience of the photographer. Thankfully, Vixen has provided one of the best beginner's guides I've ever seen to help you get started if you are new to this process.

Another factor in taking good star photos is the quality and precision of the star tracker itself — and at this, the Polarie U excels. The manual recommends the half-speed starscape mode to increase exposure time when capturing a landscape with stars above, which makes the foreground appear to move less. With the camera on manual, the ISO at 1600, and the lens at f/2.8, I experimented with 30-second exposures before moving on to longer exposures. The Polarie U worked flawlessly at every exposure time.

When I used the Polarie U, I was brought back to the first photo of the night sky I ever captured. As a kid, I had to be more inventive with my setups. To take a long exposure, I covered my lens with a scarf, taped the shutter button down, and pulled off the scarf. After five minutes, I put the scarf back over the lens and released the shutter. The result was my first image of Orion in classic black and white.

Half a century later, technology has made it easy for anyone to take wonderful photos of the night sky, thanks to trackers like the Polarie U Star Tracker.

Raymond Shubinski *is a contributing editor for* Astronomy *who loves using new astronomical equipment under clear desert skies.*

Unicorn treasures

The Winter Triangle hides more than just stars.

NGC 2301's smattering of stars has entranced many observers. What shape do you see? ANTHONY AYIOMAMITIS

As the harshness of the season slowly begins to give way to the promise of spring, let's enjoy a few wintry targets that pass by year after year with little notice.

The stars Betelgeuse (Alpha [α] Orionis), Sirius (Alpha Canis Majoris), and Procyon (Alpha Canis Minoris) form the equilateral **Winter Triangle**. This triangle frames a void that is nearly starless apart from a few dim points only visible from darker surroundings. Yet inside the triangle is a treasure trove of open star clusters ripe for binocular viewing.

Through your binoculars, extend a line from the Hunter's belt stars, as if you are going toward Sirius. About halfway along and a tad to the north, you will see two 4th-magnitude stars. The star closer to the belt is Gamma (γ) Monocerotis, while the star closer to Sirius is Beta (β) Monocerotis. Note that Beta is a striking triple star through telescopes, but resolving them takes more magnification than most binoculars offer.

Beta is, however, a great reference star for our first binocular target, open cluster **NGC 2232**. You'll find it just 2° to the star's north. The cluster's brightest star is 10 Monocerotis, a blue-white 5th-magnitude orb offset to the northwest of center. Half a dozen 8th- and 9th-magnitude cluster stars trickle southward from it in two streams. You will also notice some stars northwest of 10 Monocerotis forming a curved wedge, with 7th-magnitude 9 Monocerotis at its northern end. The overall appearance led Leland Copeland, one of the mid-20th century's most prolific deep-sky observers and authors, to nickname the cluster the Double Wedge.

Inside the [Winter Triangle] is a treasure trove of open star clusters.

Move back to Beta and glance about half a field southeast for a triangle of 5th-magnitude stars. The corner closest to Beta is marked by the orange star HD 48217. Just to its west is a small wedge of a half-dozen faint stars measuring just 7' across pointing north. You won't find this group plotted on star atlases because it is not a genuine deep-sky object. Instead, it's one of the sky's many asterisms, or unrecognized constellations — which are, after all, ultimately just line-of-sight patterns created by unrelated stars. I first stumbled upon this little configuration more than 30 years ago as I was researching my book *Touring the Universe Through Binoculars*. In the book, I referred to it as the **Unicorn's Horn** for its pointy shape. Although the stars are relatively faint, the horn is surprisingly easy to recognize because there are few background stars to muddle the view. I can just make out the horn as a misty patch through my 10x50 binoculars from my suburban backyard, while all six stars are clear through my 16x70s.

Bidding Beta farewell, head about 13° (or two binocular fields) northeast to 4th-magnitude Delta (δ) Monocerotis. A mere 13.5' to the northwest, Delta is joined by 5th-magnitude 21 Monocerotis to create a nice line-of-sight double star for low-power binoculars.

If you shift the Delta/21 Monocerotis duet toward the eastern edge of the field, open cluster **NGC 2301** will just squeeze inside the western edge. NGC 2301 is a delightful collection of 80 stars located about 2,500 light-years away. The first thing you'll notice about the cluster is a row of half a dozen faint stars set in a meandering line running north to south. Look carefully at about midspan along the line and you should also detect a hazy triangular mist of stars too faint to resolve through most binoculars. Giant binoculars may resolve some into unusual chains of stars threaded across the line. Different observers see various patterns among those stars. Copeland saw the wavy line of stars as a "golden worm," while *Astronomy* contributing editor Stephen O'Meara once christened it Hagrid's Dragon after *Harry Potter*'s Rubeus Hagrid. To my eyes, the cluster's shape is reminiscent of a bird in flight. The two wings are represented by the string of stars extending to either side of the three-sided body. Due to this appearance, I like to refer to this as the Great Bird of the Galaxy Cluster. Look for yourself and use your imagination. Then drop me a line through my website, philharrington.net, and tell me about it.

Until next month, remember that two eyes are better than one.

BY PHIL HARRINGTON
Phil is a longtime contributor to Astronomy *and the author of many books.*

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Astronomers captured this supernova, SN 2020fqv, in the act of exploding within the interacting Butterfly Galaxies. NASA, ESA, R. FOLEY (UC SANTA CRUZ), J. DEPASQUALE (STSCI)

Cosmic fireworks

Q | WHAT ARE THE DIFFERENCES BETWEEN SUPERNOVAE, KILONOVAE, AND HYPERNOVAE?

Wolfgang Golser
Tucson, Arizona

A | In Latin, *nova* means "new." In astronomy, that refers to a temporary bright "star" in the night sky. But the causes of these brief but brilliant stars are varied.

Classical novae occur in a binary star system with a white dwarf and a star close enough together that the white dwarf pulls, or accretes, material from its companion. The material — mostly hydrogen — sits on the surface of the white dwarf until enough has been gathered to kick-start a nuclear fusion reaction, the same process that powers the Sun. As the hydrogen is converted into heavier elements, the temperature increases, which in turn increases the rate of hydrogen burning. At this point, the white dwarf experiences a runaway thermonuclear reaction, ejecting the unburnt hydrogen, which releases 10,000 to 100,000 times the energy our Sun emits in a year. Because the white dwarf remains intact after blowing away this excess, a stellar system can experience multiple classical novae.

Kilonovae occur when two compact objects, like binary neutron stars or a neutron star and a black hole, collide. These mergers, as their name suggest, are about 1,000 times brighter than a classical nova, but not as bright as a supernova, which is 10 to 100 times brighter than a kilonova.

There are two basic ways to get a supernova. The type of supernova most people think of is a dying star's last hurrah, known as a type II or core-collapse supernova. At the end of a massive star's life, it no longer has the energy to support itself against gravity and collapses, the core squeezing itself into as tight a ball as possible. The implosion reverberates outward, exploding the leftover material into space. The other type of supernova, a type Ia supernova, occurs when a white dwarf in a binary star system gobbles up too much material from its companion. Unlike with a classical novae, this white dwarf experiences a thermonuclear reaction in its core. Once it crosses a critical mass threshold, it collapses and violently expels its outer layer, tearing itself apart. In both cases, a new stellar remnant — either a neutron star or a black hole — is born.

A hypernova — sometimes called a collapsar — is a particularly energetic core-collapse supernova. Scientists think a hypernova occurs when stars more than 30 times the mass of the Sun quickly collapse into a black hole. The resulting explosion is 10 to 100 times more powerful than a supernova.

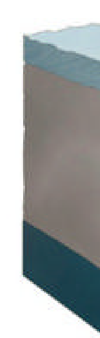
Caitlyn Buongiorno
Associate Editor

Q | HOW IS IT THAT EARTH IS THE ONLY KNOWN PLANET WITH ACTIVE PLATE TECTONICS?

Erik McKenna
Stamford, Connecticut

A | Earth is special in that it has two things that other terrestrial planets don't: an abundance of internal heat, from when our planet was molten rock, and liquid water. To understand why our planet is unique in this regard, let's first look at Earth versus Mars.

Earth is relatively large for a rocky planet. Its sheer amount of mass has allowed it to hold onto its internal heat over billions of years. The heat causes Earth's surface to deform and plays a key role in ensuring that



Earth's outer surface layer, called the lithosphere, doesn't become too cold and thus too rigid to move. But Mars is smaller than our planet. Because of this, the Red Planet has cooled at a much faster rate. Mars' lithosphere has become very rigid — too rigid to be broken into plates.

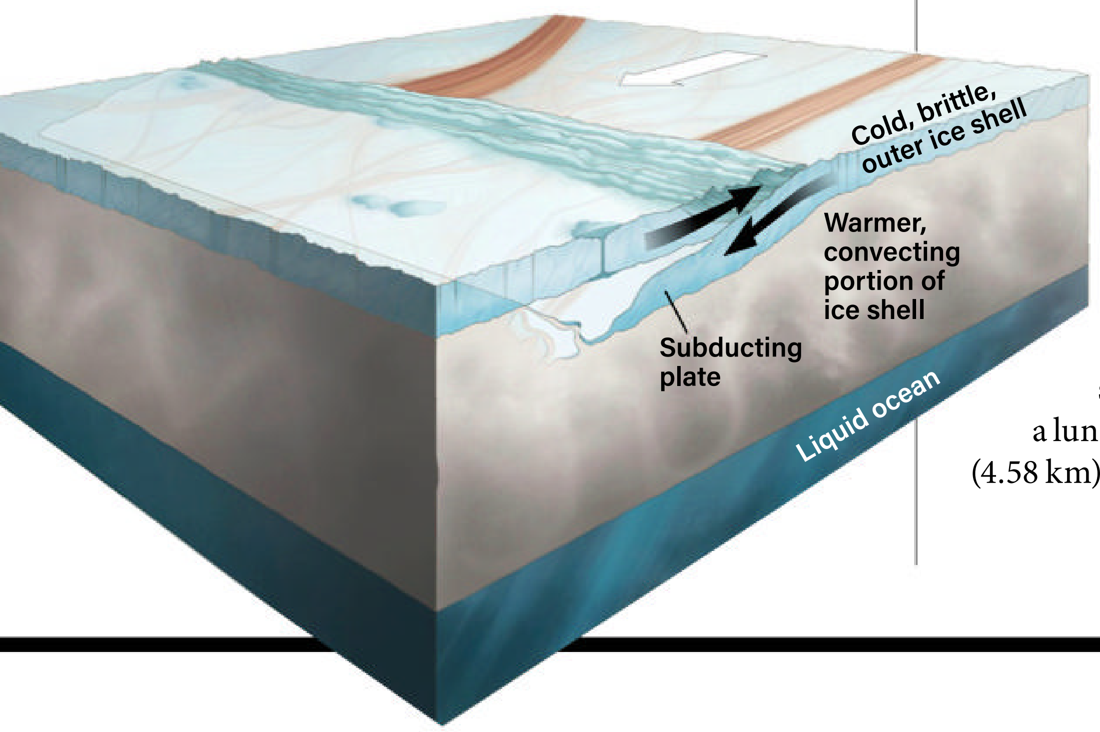
Heating isn't the only thing at play when it comes to plate tectonics. Venus is about the same size as Earth, so theoretically, one might think it's also likely to have moving plates. But it doesn't. While heating is enough to stave off a rigid lithosphere, it isn't enough to move Earth's plates. That's where liquid water comes into the equation. On Earth, interior water lubricates the tectonic plates, allowing them to flow and slide past one another, but there is no water in Venus' interior.

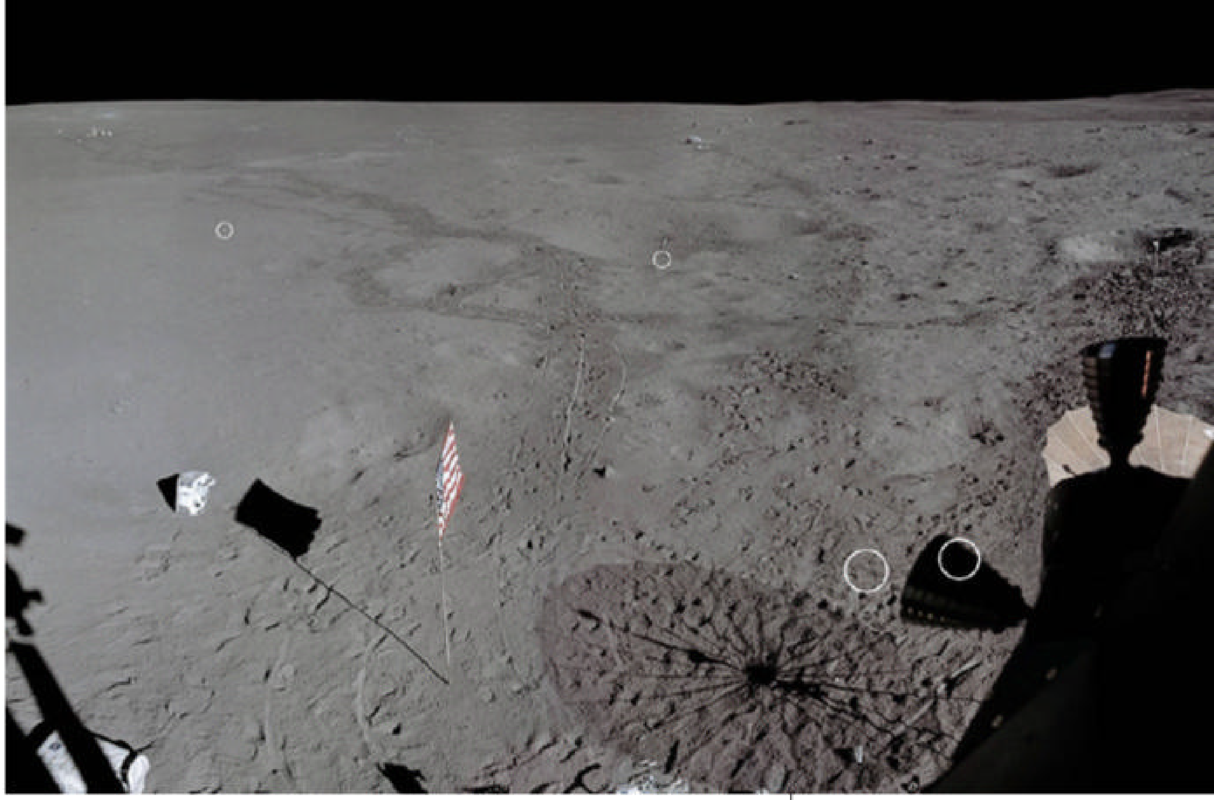
To be clear, tectonic deformation is currently occurring in the outer layers of Venus and Mars, and once took place on Mercury. However, because the outer layers of these planets are not broken up into plates, we consider these planets to be one-plate planets. So, Venus and Mars still experience tectonics, just not plate tectonics.

Earth may not be the only body in the solar system to experience plate tectonics, however. Jupiter's icy moon Europa is covered in a shell of cold, brittle ice that is believed to float atop a warmer, fluid ice layer. Like Earth's plates, when two plates of this cold ice hit each other, one of these plates is able to slide beneath the other into Europa's interior. Scientists have also observed evidence of water upwelling to the surface of this moon, much like magma wells up from vents on Earth.

Lynnae Quick
Ocean Worlds Planetary Scientist, Goddard Space Flight Center, Greenbelt, Maryland

EUROPA PLATE TECTONICS





ABOVE: Image specialist Andy Saunders analyzed archival stills taken by the astronauts and was able to measure the distance of Shepard's second shot. NASA/JSC/ASU/ANDY SAUNDERS

BELOW LEFT: Scientists believe that Europa has plate tectonics, similar to Earth. This artist's concept illustrates how two icy plates would interact on the moon. *ASTRONOMY*: ROEN KELLY, AFTER NASA/NOAH KROESE, I.NK

Q | SOME 50 YEARS AGO, ALAN SHEPARD HIT SOME GOLF BALLS ON THE MOON. JUST HOW FAR COULD A TOUR PRO HIT A GOLF BALL ON THE MOON IF THEY WEREN'T ENCUMBERED BY A SPACESUIT?

Jim Knoll
Vancouver, Washington

A | Alan Shepard shanked his first shot into a crater, but estimated that his second reached a distance of about 600 feet (183 meters). Recent evidence from remastered photos taken during the mission, however, suggests that Shepard managed to only hit his second golf ball some 120 feet (36.5 m).

To be fair, Shepard wasn't just restricted by his spacesuit. His makeshift golf club wasn't exactly regulation — just a 6-iron head attached to a collapsible tool designed to scoop lunar rocks.

According to PGA Tour stats for 2021, the average tour pro off the tee imparts a ball speed of 170.4 mph (274.2 km/h) and launches the ball at 10.52°. So, in lunar gravity, an average tour pro's tee shot would carry about 4,170 feet (1,271 m). (On Earth, air actually helps a golf ball fly farther: Clubs impart backspin to a ball, which helps it generate aerodynamic lift and keeps it aloft.)

But a pro could still do better on the Moon. On Earth, golfers use low launch angles to send the ball further, minimizing the effects of drag. The lack of air resistance on the Moon means you could use a true ballistic trajectory with the ideal launch angle of 45°.

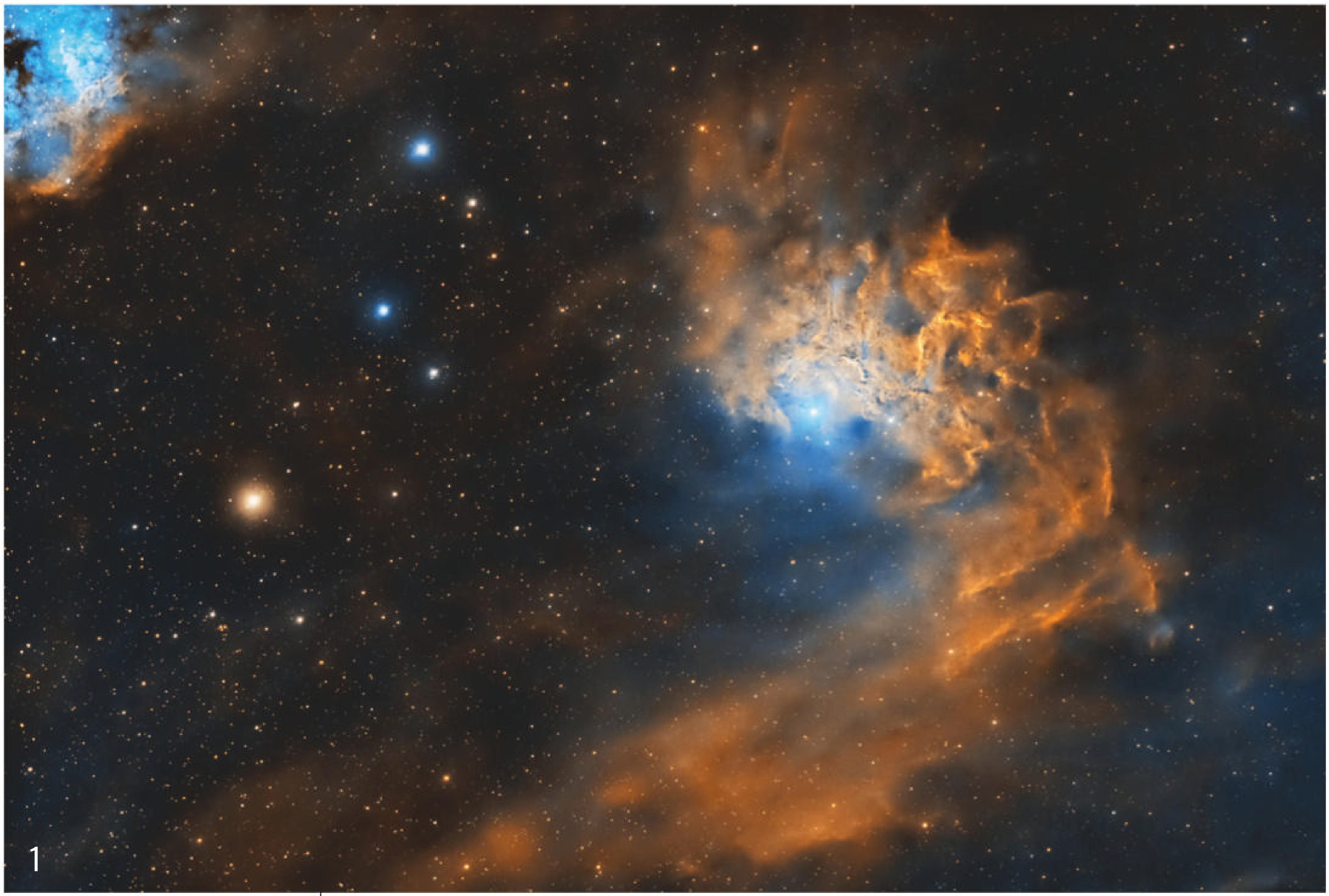
So, if you were able to launch a ball at a 45° angle at a speed of 170.4 mph (274.2 km/h) on the Moon, the ball would travel about 2.21 miles (3.55 km). Bryson DeChambeau, with his 2021 average ball speed of 190.72 mph (306.93 km/h), could hit a lunar golf ball even farther than that: 2.76 miles (4.58 km).

Mark Zastrow
Senior Editor

SEND US YOUR QUESTIONS

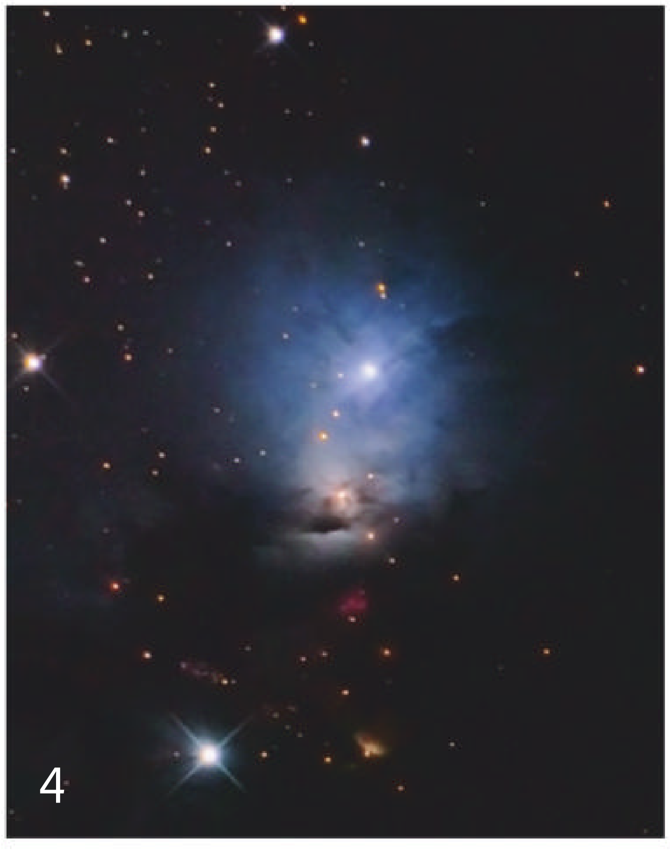
Send your astronomy questions via email to askastro@astronomy.com, or write to Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

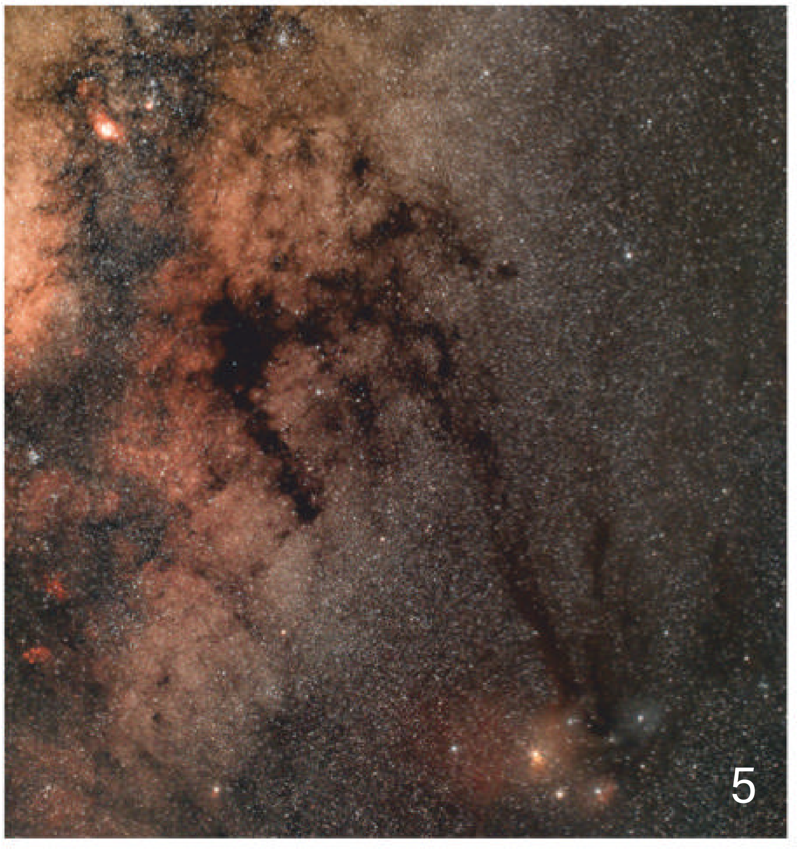
Cosmic portraits



1. ROGUE WAVE OF FIRE
The billowing gas surrounding the star AE Aurigae gives the Flaming Star Nebula (IC 405) its name. But in this narrowband image processed in the Hubble palette and given a slight shift in composition, the tendrils take on the frothy appearance of a rogue wave. This image, taken over nine hours and 45 minutes with an 8-inch telescope, is reminiscent of the woodblock prints from the Japanese artist Hokusai. • ***Chuck Ayoub***

2. TAKING ITS TIME
The Nov. 19, 2021, partial lunar eclipse was the longest in 580 years, lasting three hours and 28 minutes. Although it wasn't a total eclipse, it was close: Only 3 percent of the lunar disk was outside Earth's umbra. At mid-eclipse, Luna was just 5.5° from the Pleiades (M45) in Taurus, as captured in this composite image. • ***John Vermette***





3. SOLAR ERUPTION
The Sun rises over the Iranian peak of Mount Damavand — a dormant stratovolcano — in this shot framed from roughly 44 miles (70 kilometers) away. In the foreground is Tehran's Milad Tower. The imager used a Canon 6D and a 3-inch scope to zoom in on the scene. • ***Ali Shafieian***

4. TALE OF TWO NURSERIES
Some 1,000 light years away in the constellation Perseus, NGC 1333 is a reflection nebula — a cloud of gas scattering blue light from young stars in the northern half of an open cluster. By contrast, the southern half of the cluster is shrouded in the dense, cold dust of the dark nebula Barnard 205. But the splotches of color bursting through indicate that it, too, is full of star formation. This image represents 12.6 hours of exposure with an 8-inch scope and a Canon EOS 60D DSLR. • ***Jared Bowens***

5. DARK NEIGH-BULA
The Dark Horse Nebula spans 10° and seems to prance across the Great Rift of the Milky Way, the dark dust lane that runs through the band of our galaxy. Its hindquarters and back legs make up the Pipe Nebula, which contains no fewer than five separate dark nebulae listed in Edward Emerson Barnard's catalog. This wide-field image was taken with a Canon EOS Ra mirrorless camera and an EF 50mm f/1.4 prime lens at f/4.
• ***Gianni Tumino***

6. ALL THAT'S LEFT
W63 is the expanding shell of debris and excited gas resulting from a supernova that exploded around 20,000 years ago in Cygnus. This image was made with Hα and OIII filters, and 38 hours of exposure with a 4-inch scope.
• ***Alberto Ibañez***

SEND YOUR IMAGES TO:
Astronomy Reader Gallery, P.O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to **readergallery@ astronomy.com.**

HEADING STRAIGHT FOR THE HEART

Open star clusters are born from clouds of gas and dust. The relationship isn't always obvious, however. Some clusters, such as the Beehive (M44) in Cancer, have long since exhausted the material needed to make new stars and now appear as isolated groups. Others remain embedded within their natal clouds and are invisible at optical wavelengths. Melotte 15, pictured here, occupies a photogenic middle ground. Located at the center of the Heart Nebula (IC 1805) in Cassiopeia, this cluster boasts dozens of stars, several of which contain nearly 50 solar masses. Melotte 15 lies 7,500 light-years from Earth and appears about 1.5 million years old, mature enough that its stars shine through, but youthful enough that plenty of gas remains nearby to create future stars. CANADA-FRANCE-HAWAII TELESCOPE/COELUM—J.-C. CUILLANDRE & G. ANSELMI

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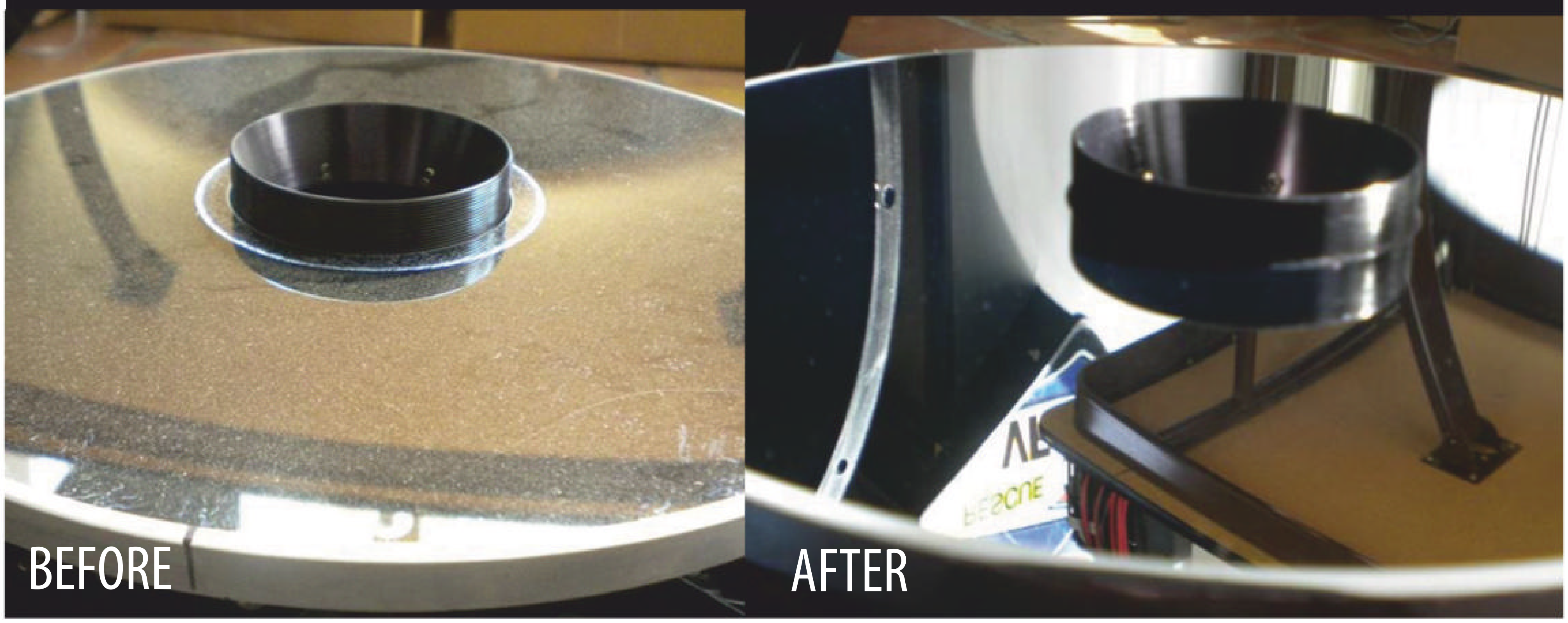

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*Photos by: James Olson, Right Ascension, LLC**

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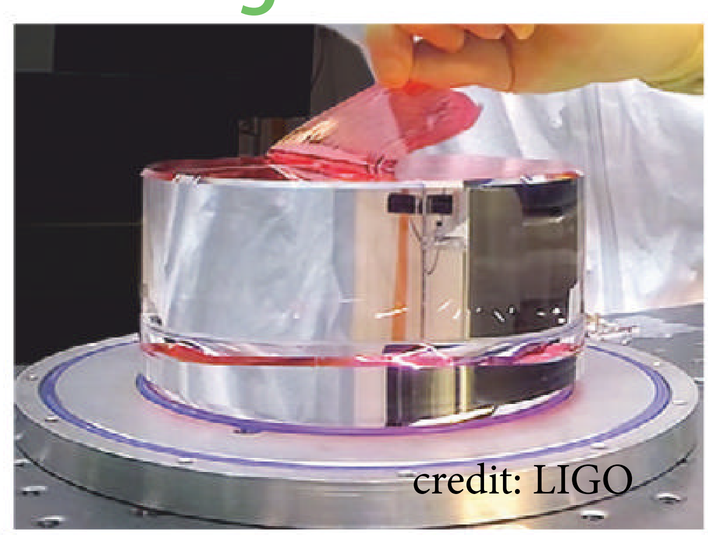

credit: LIGO

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May 2022
Darkness shades the Full Moon

Early May offers evening skygazers only one planet, and it's not the most spectacular. **Mercury** lies just 5° high in the northwest 30 minutes after sunset. At its best on the 1st, the inner planet glows at magnitude 0.5 and will be hard to spot against the bright twilight. A telescope reveals Mercury's 8"-diameter disk and one-third-lit phase.

Several hours elapse before the next planet emerges, but the wait will be worth it. **Saturn** rises near 1 A.M. local time May 1 and about two hours earlier by month's end. The ringed planet shines at magnitude 0.7 against the backdrop of eastern Capricornus, 2° north of magnitude 2.8 Delta (δ) Capricorni. Although Delta ranks as the Sea Goat's luminary, Saturn appears seven times brighter.

Saturn's appearance through a telescope improves as it climbs during the predawn hours. As with any planet, Saturn looks better when it's high in the sky because we then see it through less of Earth's turbulent atmosphere. The ringed world will reward your patience with stunning views. In mid-May, its beautiful ring system spans 38" and surrounds a slightly flattened disk that measures 17" across. The rings tilt 12° to our line of sight and show modest structure through small scopes.

The autumn sky gains a touch of color when **Mars** rises a couple of hours after Saturn. The Red Planet paints Aquarius with its ruddy hue until May 19 when it crosses into Pisces. Mars brightens from magnitude 0.9 to 0.6 during May, a brightening that will continue as it approaches opposition in December. Unfortunately, the planet's 6"-diameter disk won't show any detail through most amateur instruments.

Mars stands 16° west of **Jupiter** as May begins, but the gap narrows by about 0.5° a day. That sets up a close conjunction between the two worlds late this month. On May 29, the Red Planet passes 0.6° south of the gas giant.

As splendid as this encounter may be, Jupiter has a far more striking embrace in early May. On the 1st, brilliant Venus stands 0.2° to Jupiter's upper right. Although this conjunction officially took place at 19h UT on April 30, the two planets appear closest on the 1st for observers in Australasia.

A telescope always delivers striking views of Jupiter. In mid-May, the giant world spans 36" and shows a wealth of detail in its colorful cloud tops. Look for two parallel dark belts, one on either side of a zone that coincides with the planet's equator. Jupiter's four bright moons — Io, Europa, Ganymede, and Callisto — also show up through small amateur scopes.

Venus draws away from Jupiter as May progresses. The magnitude –4.0 planet begins the month in Pisces, makes a four-day sojourn through Cetus the Whale during May's second week, then returns to the Fish before crossing into Aries the Ram on the 31st. A telescope shows Venus' disk, which spans 15" and appears 73 percent lit at midmonth.

A waning crescent Moon occults Venus on May 27. Observers in southern Madagascar can witness this event in a dark sky. From Tiliara, Venus disappears at 0h50m UT and reappears at 1h27m UT. The Moon takes nearly a minute to hide and later reveal the planet's disk.

A total lunar eclipse occurs the night of May 15/16. Viewers in South America are ideally placed because the whole eclipse takes place with the Moon high in a dark sky. The umbral phase runs from 2h28m UT to 5h55m UT with totality lasting from 3h29m UT to 4h54m UT. The Moon should turn a beautiful orange color during the 85 minutes of totality.

The starry sky

Midevenings in May provide gorgeous views of Crux the Cross at its peak altitude in the south. Musca the Fly borders Crux to the south while Centaurus the Centaur surrounds the Cross on its other three sides. Crux and Centaurus hold plenty of striking deep-sky objects, including the Coal Sack dark nebula, the Jewel Box Cluster (NGC 4755), and Alpha (α) Centauri. With this wealth of wonders, it's not surprising other deep-sky standouts get overshadowed.

But you shouldn't pass on the chance to view the Blue Planetary Nebula (NGC 3918). Like other planetaries, this nebula represents the death throes of a Sun-like star. As such a star nears the end of its life, it puffs off its outer layers, which glow from high-energy ultraviolet radiation released by the dying star's core. Some early observers thought their disks looked like those of the planet Uranus, hence the name.

NGC 3918 lies in Centaurus, near the northwestern corner of Crux. Although it's tough to star-hop to the nebula, you can find it easily through a small telescope with the help of a detailed star chart. If you have a go-to mount, dial in a right ascension of 11h50.3m and a declination –57°11' (2000.0 coordinates).

English astronomer John Herschel discovered this planetary in 1834 while observing from the Cape of Good Hope. He called it a perfect planetary disk and was clearly struck by its color, writing "It is of a most decided independent blue color." He also noted an 8th-magnitude orange star 10' to its north, which made the nebula's blue color even more obvious.

Through amateur instruments, NGC 3918 appears as a round disk about 8" to 10" across. Appropriately, it looks remarkably like a larger and bluer version of Uranus.

STAR DOME

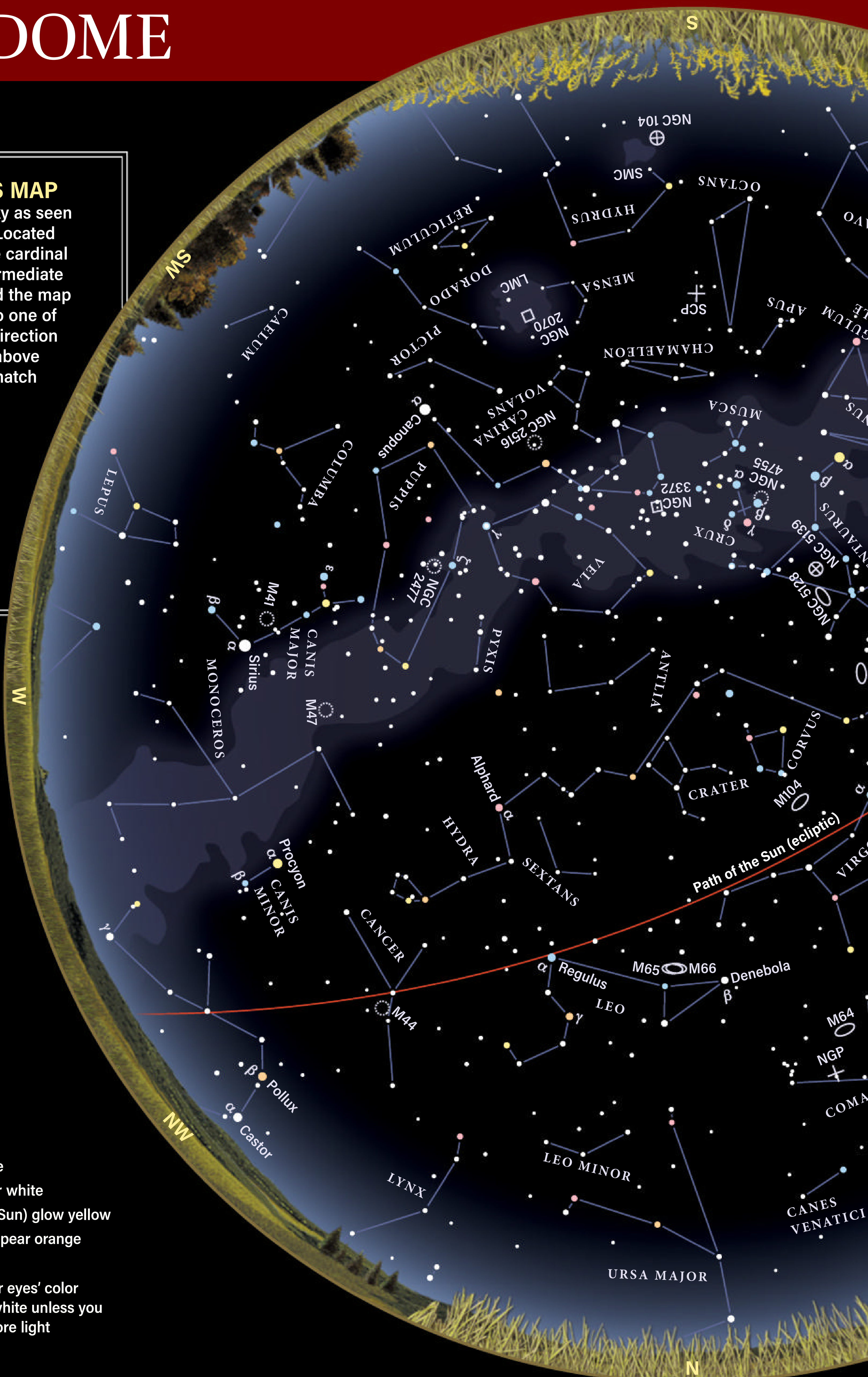
HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. May 1
8 P.M. May 15
7 P.M. May 31

Planets are shown at midmonth



MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

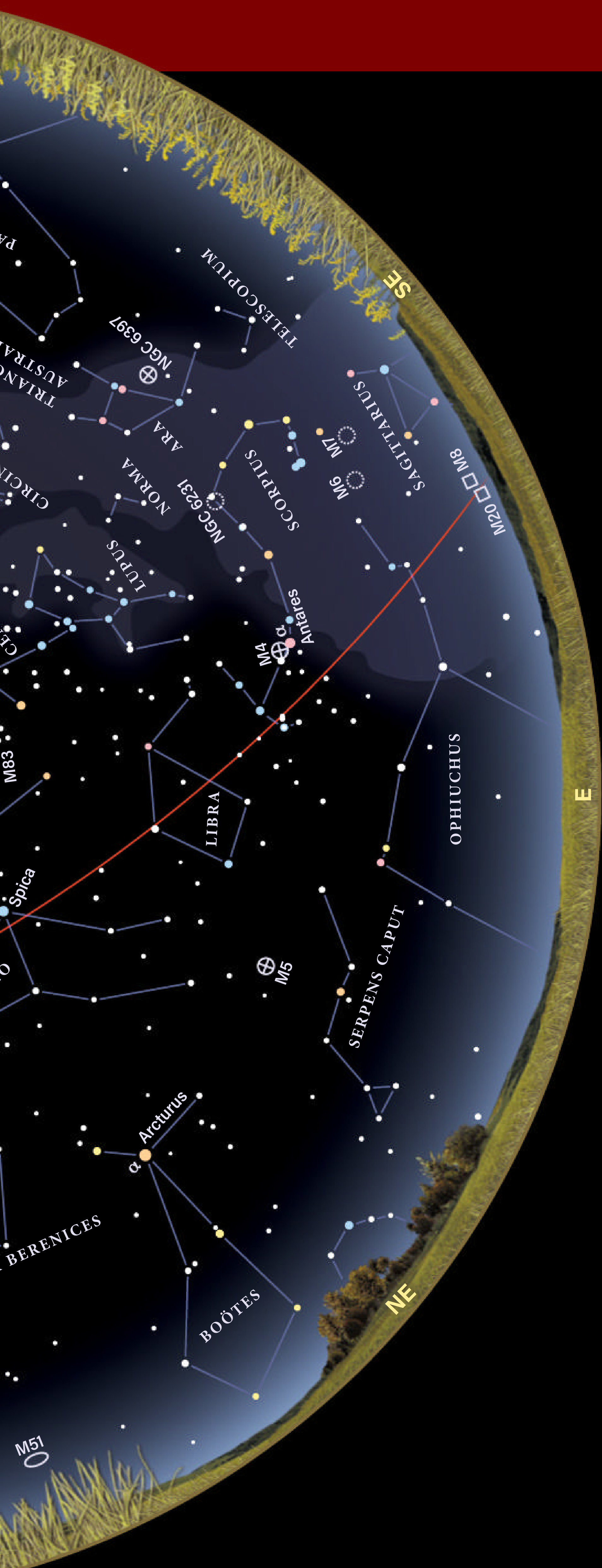
- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



MAY 2022

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

2 The Moon passes 1.8° south of Mercury, 14h UT

4 The Moon passes 0.008° south of dwarf planet Ceres, 14h UT

5 Uranus is in conjunction with the Sun, 7h UT

The Moon is at apogee (405,285 kilometers from Earth), 12h46m UT

6 Eta Aquariid meteor shower peaks

9 First Quarter Moon occurs at 0h21m UT

10 Mercury is stationary, 23h UT

16 Full Moon occurs at 4h14m UT; total lunar eclipse

17 The Moon is at perigee (360,298 kilometers from Earth), 15h27m UT

Mars passes 0.6° south of Neptune, 23h UT

21 Mercury is in inferior conjunction, 19h UT

22 The Moon passes 4° south of Saturn, 5h UT

Last Quarter Moon occurs at 18h43m UT

24 The Moon passes 4° south of Neptune, 10h UT

The Moon passes 3° south of Mars, 19h UT

25 The Moon passes 3° south of Jupiter, 0h UT

27 The Moon passes 0.2° south of Venus, 3h UT

28 The Moon passes 0.3° south of Uranus, 14h UT

29 Mars passes 0.6° south of Jupiter, 0h UT

30 New Moon occurs at 11h30m UT